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APPLIED MECHANICS REVIEWS

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MODERN DEVELOPMENTS IN THE MECHANICS OF CAVITATION

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OFFICE OF NAVAL RESEARCH

INTRODUCTION

IN the decade just passed, there has been a significant increase in research on various aspects of cavitation (and boiling) phenomena. This activity has been stimulated, on the one hand, by the demands of rapidly developing technology in the fields of shipbuilding and hydraulic engineering (which, traditionally, have been concerned with the effects of cavitation—either unwanted or sought: loss of efficiency, damage to materials, noise; supercavitating systems), in the field of underwater signaling (background noise, absorption of acoustical power), and in hydroballistics (with its problems of drag rise and missile stability and control). On the other hand, research has lately been focused to a large extent following recognition of the role of cavitation in such widely diverse disciplines as chemical processing (acceleration of reactions and mixing processes, industrial cleaning), medicine (diver's bends, bullet wounds; speculations concerning brain trauma or concussion under blows) and, more recently, by the practical importance of its occurrence in liquid metals (e.g., as heat-transfer media in nuclear reactors) and cryogenic liquids (rocket fuels, etc.); even the possibility of cavitation accounting for the geophysical phenomenon of "potholes" has been suggested.

The discussion here will be restricted to a description of recent research trends and of the status of physical problems that appear to be pivotal in acquisition of ability to cope with the consequences of cavitating flows and will exclude, in general, detailed consideration of cavitation produced by heat addition (boiling) and acoustical pressure waves as well as problems of pure liquids (e.g., ultimate tensile strength). Nevertheless, the topics considered will be recognized as basic to many aspects of these problems as well as to the types of cavitation in the examples cited above.

Pertinent historical and technical background for the present survey will be found in works by Bateman (1), Ackeret (2), and Eisenberg (3,4) and in the references therein. Compilations of particular interest to the naval architect and hydraulic engineer are given in references (5) and (6).

PRESENT IDEAS AND CONTROVERSIES ON CAVITATION INCEPTION

The Role of Nuclei

It is now the generally accepted view that the inception of cavitation in ordinary liquids is associated with the growth of nuclei (often submicroscopic in size) containing vapor, undissolved gas, or both, which are present either within the liquid or in crevices on bounding walls. On the basis of physical arguments (4), it is unlikely that completely dissolved gases can play a dominant role in inception, although in certain cases, explained below, such dissolved gases may become important during the inception process. The work of Harvey et al (7) is of particular importance in this connection, having demonstrated that water, saturated with air, when "denucleated" by prior application of large pressures exhibited very high fracture strength. Thus, the presence of such nuclei is taken to account for cavitation onset at pressures of the *order* of vapor pressure. (These ideas are now receiving attention in attempts to predict boiling onset and superheat values. While the scope of this article precludes discussion of the boiling problem, see e.g. Ellion (8), it is of interest to note that the idea of undissolved nuclei as centers for boiling at small superheats was already extant at the turn of the nineteenth century, see e.g. Aitken (9), but seems to have been overlooked for many years. Thus, the sequence of ideas has come full circle.)

Although the *function* of nuclei is now considered to be well understood, there remain essential questions concerning their nature and behavior and the relation of such nuclei to total gas content and, consequently, to the actual pressures for inception of cavitation.

Effects of Air Content; Persistence and Characterization of Nuclei

The effects of total air content on cavitation inception has been the subject of many investigations, of particular interest here being those of Numachi and Kurokawa (10), Crump (11, 12), and Williams and McNulty (13), all of whom used venturi-type nozzles. In all of these experiments it was shown that

inception pressures are reduced as air content is reduced, with tensions evident in undersaturated water. For sea water, which is supersaturated, thus presumably containing a large number of undissolved nuclei, bursts of cavitation were observed at pressures well above vapor pressure (11). While the trends in these experiments were fairly definitive, the very large scatter of results is indicative of the need for understanding the behavior and distribution of nuclei, i.e., the mechanisms by which nuclei are stabilized in a fluid and the characterization of nuclei content, e.g., a "spectrum" or description of number and distribtuion in size (3).

There is evidently very little difficulty in accounting for the stabilization of nuclei in supersaturated liquids or in crevices on bounding walls. On the other hand, studies by Epstein and Plesset (14) of the rates of gas solution by diffusion show that gas bubbles will dissolve in undersaturated liquids and even in systems in equilibrium, in the latter case assisted by surface tension. A number of suggestions have been made to account for nuclei in undersaturated liquids and in liquids that have been boiled or otherwise degassed. The most common postulate is the presence of microscopic dust particles on which gas or vapor nuclei are stabilized; a review of the evidence for such particulate matter has been given by Rosenberg (15). It has been suggested that in water surface active materials (4) and the interaction of hydrogen and hydroxyl ions adsorbed on the surface of nuclei (16) may play a role in certain situations. Another hypothesis, based on the assumption of an organic skin which prevents diffusion until ruptured by pressure reduction, has been advanced and examined in some detail by Fox and Herzfeld (17). Whatever the mechanism (or mechanisms) by which nuclei are stabilized, this question is of some practical importance both in establishing the threshold for unstable growth (cavitation inception) and in determining the rates and limits for resorption under pressure (thus affecting the design of water-tunnel resorbers, for example).

Some progress has been made on characterization of nuclei content, although for some time to come it may be expected that measurements of total air content will continue to be part of standard procedure in tests of cavitating systems. A summary of a number of types of total gas content meters now in use and pertinent source material will be found in reference 16. A new type of total air content meter which allows continuous monitoring of the test liquid and has much shorter time lag than those generally available has been reported by Fitzpatrick and Harkleroad (18). This is singled out for mention since it evidently has the possibility of being adapted for measurements of *total undissolved* gas. The most important development in this respect, however, is the work of Strasberg (19), who has been able to obtain a measure of the nuclei size and number in a stationary sample by utilizing the sound absorption properties of nucleated liquids. The sensitivity of the method is limited, however, to a threshold imposed by damping in the liquid and by the container walls.

The Environmental Conditions; Cavitation in Shear Flows

By "environmental" factors is meant here the hydrodynamical pressure conditions which tend to promote growth of nuclei. One of the most significant recent developments is recognition of the importance of shear flow phenomena in several phases of the cavitation process. In particular, boundary-layer influences and turbulence in shear flows are receiving attention. The role of the boundary layer was examined by approximate arguments by Eisenberg in 1950 (4). It was concluded that, in laminar boundary layers, cavitation would probably occur first at the boundary while in turbulent layers it would most likely occur first in a region of highest turbulence intensity at a small distance from the wall; in the latter case due to the lower pressures occurring in the turbulent region than at the wall. In a series of experiments designed to study the effect of scale on inception, Kermeen, McGraw, and Parkin (20) have confirmed the importance of boundary-layer effects. In these experiments, cavitation originated in the laminar portion of the boundary layers on a series of bodies of revolution; bubbles were observed to grow at the body, remaining attached until reaching a certain "critical" size (less than the boundary-layer thickness) before being swept downstream. Experiments designed to investigate the onset of cavitation in turbulent boundary layers have been carried out by Daily and Johnson (21). While they found that cavitation did, in fact, occur at some distance from the wall, the region of maximum activity did not coincide with the region of maximum turbulent velocity intensity.

In the case of wakes, it has been suggested (22) that the observed appearance of many so-called steady-state cavities is associated with the turbulent pressure fluctuations in the region of high shear at the boundary of the wakes, and measurements have been made of the inception pressure as a function of Reynolds number in this region behind disks (20). Shal'nev (23) has studied cavitation in the wake of a cylinder and correlated the Strouhal number for cavitating wake oscillations with Reynolds number. Studies of cavitation in the boundaries of free jets have been reported by Rouse (24) and by Roesler (25). All of these investigations indicate the need for more detailed descriptions of the pressure fluctuations in turbulent flows. It would seem that the mean pressure fluctuation will be of little value in predicting inception unless modified by factors representing a "length scale" (to account for only those fluctuations which are of wave length large compared with nuclei of minimum critical size) and a "time scale" (to represent the required "hold-on" time) (3).

Other examples of cavitation in shear flows are cavitation about surface roughnesses in a boundary layer reported by Shal'nev (26), who gives empirical criteria for inception about various types of discrete roughness elements, the effects of local separation in boundary layers shown by Rouse and McNown (27), and cavitation in gaps studied by Shal'nev (28).

Growth of Nuclei; Scale Effects

The range of equilibrium diameters of gas or vapor bubbles which exist in a state of dynamic instability and thus are available for growth under the influence of a pressure or temperature disturbance has been examined by Dergarabedian (29) and in greater detail by Zwick (30), among others. In general, the upper value represents the limit above which a bubble will grow by vaporization (rather than gas diffusion) and the lower value the limit below which a bubble will dissolve. To distinguish between the growth of a bubble by vaporization (i.e., almost explosively) and by the (slow) diffusion of dissolved gas into the bubble, Blake (31) defined these two processes as "vaporous" and "gaseous" cavitation and examined the conditions under which each would occur. Based on these results, Strasberg (19) has shown that, while, for vaporous cavitation, pressures equal to or less than vapor pressure are always required regardless of initial nucleus size, pressures either above or below vapor pressure can initiate gaseous cavitation depending on initial radius and partial gas volume. Regarding the rate of growth of nuclei in vaporous cavitation, the computations of Noltingk and Neppiras (32) show that the duration of the critical pressure for growth need only be of the order of the natural period of the nucleus (i.e., of the order of microseconds for nuclei in the available range). This result has been emphasized by Strasberg (19, 33) in an examination of a process in which gaseous diffusion proceeds into a nucleus too small for vaporous cavitation at the ambient pressure until the critical size for vaporous cavitation is reached. The importance of this observation in the problem of scale effects is evident.

In the experiments on effects of scale cited above (20), a definite dependence of critical (inception) cavitation number on model size and absolute flow velocity was found. The

critical cavitation numbers for each model were below those corresponding to the minimum pressure coefficient and only approached this value as stream velocity was increased; in addition, the values were ordered by model size, those of the largest model lying nearest the value corresponding to the minimum pressure coefficient. Certain "hysteresis" effects were noted in these experiments, the critical cavitation numbers depending on whether the critical pressure was taken to be the first appearance of cavitation or the final disappearance from a fully-cavitated condition. Such effects were also noted, but not measured, in the small nozzle used by Crump (11); on the other hand, in a much larger nozzle, Olsen (34) could find no effects of this type. (A more complete discussion of these various results is given in reference 16).

TRANSIENT (BUBBLE) CAVITIES

Dynamics of Transient Cavities

"Transient" cavities are defined to be small individual bubbles which grow, sometimes oscillate, and eventually collapse and disappear. The first definitive photographs of the life of such cavities were made in 1928 by Mueller (35) in experiments on hydrofoils; in his experiments, no rebound of the collapsing bubbles was observed. In 1948, Knapp and Hollander (36) published photographs in which several cycles of bubble growth and collapse were evident. On the basis of experiments by Harrison (37) in which a kind of air bubble "seeding" process was used, the difference in behavior can be accounted for by the presence in the nuclei of a sufficient quantity of air to store enough energy for rebound.

Plesset (38), employing Rayleigh's (39) theoretical formulation for collapse of a spherical cavity in incompressible inviscid fluid but including the effect of surface tension and comparing with the experimental results of Knapp and Hollander (36), has shown that, in the region from maximum radius down to about 1/4 the maximum radius, the motion can be predicted with fair accuracy as long as the bubble is approximately spherical. An important further approximation taking into account the effects of compressibility was carried out by Gilmore (40), who showed that the bubble wall velocity U varies as $R^{-\frac{1}{2}}$ as $R \rightarrow 0$ (R, bubble radius) in a compressible liquid, whereas in the Rayleigh approximation $U \sim R^{-\frac{3}{2}}$. Poritsky (41) and Shu (42) have carried out computations specifically to determine the effects of viscosity and surface tension, but for an incompressible fluid, and show large effects of viscosity in retarding both growth and collapse, while for surface tension some cases are worked out to illustrate the effects in retarding growth and accelerating collapse. Assuming a slightly compressible liquid and using the acoustic approximation, Trilling (43) has computed the oscillations of a bubble filled with a perfect gas. He finds that the pressure at the bubble wall when the gas motion involves a series of shock waves is essentially the same as it would be if the gas were compressed uniformly and isentropically. Heat-transfer effects associated with evaporation and condensation have been studied by Zwick (30) and Zwick and Plesset (44) for an incompressible, inviscid liquid; during both growth and collapse, the motion is retarded.

Under what conditions the various effects mentioned above will be of practical importance during collapse are still to be determined since instability of the bubble surface may occur long before such factors as viscosity and vapor compression seriously alter the motion.

Stability of Transient Cavities

Several causes of instability may be identified immediately: wall proximity, examined by Rattray (45), pressure gradients along the path of the bubble, and "Taylor instability", i.e., the instability of an interface between light and heavy fluids accelerated one toward the other (46). Apparently the first considerations of the stability of spherical bubbles were made by Riabouchinsky (47), while the first published study connecting the instability in a spherical interface with Taylor instability seems to be that of Binnie (48). The latter work contained errors which were corrected by Plesset (49), who derived the differential equation for the behavior of the amplitude of a small perturbation on the purely radial motion of a nearly spherical interface. The same problem for a vapor-filled cavity was later carried out by Plesset and Mitchell (50). Briefly, the latter found that an expanding cavity is essentially stable while a collapsing cavity is, in general, unstable. The stability conditions have also been discussed by Birkhoff (51). The most complete examination of Taylor instability for spherical bubbles, including the effects of rotational flow and viscous flow, has been carried out by Pennington (52).

Experimental examples of cavitation bubble instability have been reported by Ellis (53), who obtained a remarkable set of photographs showing the complicated surface distortions in a collapsing cavity (perturbed by hydrostatic pressure gradient and the drag associated with rise of the bubble). Kornfeld and Suvorov (54) have shown instabilities of bubbles in a pressure field produced by a magnetostriction oscillator.

STEADY-STATE AND WAKE CAVITATION

It is characteristic of some cavitating flows that the cavity appears as a large, smooth, stationary surface. Such cavities often appear to be filled only with vapor or air (or both). On the other hand, a cavitating region made up entirely of small, transient cavities may exhibit the properties of a steady cavity in that the average envelope of such a region does not vary with time. The basic features of steady-state cavities (determined from experiments in axisymmetric flow) were given by Reichardt in 1945 (55). Since that time, the structure of such cavity flows has been found to be much more complicated than expected (22). In particular, it is necessary to distinguish between cavitation in a wake flow and truly free-streamline flow, the relation between such flows, and the transition from one to the other.

It has been shown (20,22) that, in a wake, cavitation may occur first in more-or-less well-defined vortexes along the wake boundaries. As would be expected, the average envelope in such cases does not exhibit the properties of a free-streamline flow. As the cavitation number is lowered, the cavitated region often appears to have properties of both a wake flow and a free-streamline flow (3,4). The cavitated region may remain filled with a mixture of liquid and gas phase, or the cavity may grow and collapse periodically, being filled completely by the liquid entering at the down-stream end and then reopened by evaporation and entrainment of the liquid along the boundary of the cavity. Finally, under conditions still but incompletely understood, the entrained mass is swept out entirely, the reentrant jet possesses insufficient momentum to fill the cavity (due to viscous dissipation, gravity effects), and the cavity remains gas filled; see, e.g., (3), (16). The collapse and formation processes have recently been studied on circular cylinders by Shal'nev (23,56), some of whose results have been mentioned previously, and Knapp (57), who was able to photograph in some detail the growth and filling of a cavity formed on a body of revolution.

A problem of some importance which has received very little attention is that of the prediction of the location of the leading edge of a steady-state cavity in a region of finite curvature on a body. The situation is, of course, clear for bodies on which the separation point is fixed (disks, cones), i.e., is not a function of the cavitation number. A discussion of the theoretical consequences has been given by Birkhoff (58). Movement of the separation point has been observed on hemispherical and ellipsoid shapes (3, 22), and measurements

of the point of separation as a function of cavitation number have been made on cylinders by Martyrer (59) and on spheres by Wayland and White (60) and Hsu and Perry (61). The problem is complicated by the role of the boundary layer (62), and no studies of boundary-layer-cavity interaction have as yet been made in this connection.

CAVITATION DAMAGE

In spite of a rather impressive accumulation of data, hypotheses, and literature on the mechanism of cavitation damage, the perennial controversies apparently continue with undiminished vigor. To outline in understandable detail the present status of the many theories of damage (mechanical, mechanochemical, electrochemical, thermoelectric, etc.) and the evidence for correlating factors (e.g., material hardness, tensile strength, fatigue limits, corrosion fatigue behavior, etc.) would require a comparable monograph devoted entirely to this subject. Thus, the following remarks are restricted to recent developments which seem indicative of research trends. A brief review of the various damage theories and the bases of the controversies is given in reference 3; the very thorough work of Nowotny (63), who also lists an extensive bibliography, and the experiments of Rheingans (64) are particularly fruitful as background material.

Two recent works provide additional evidence for mechanical failure. Elaborate researches by Glickman, Tekht, and Zobachev (65), using a magnetostriction oscillator, and a similar study by Plesset and Ellis (66), using a barium titanate transducer (67), have confirmed that plastic deformation (cold-working) occurs initially with damage progressing in a manner completely characteristic of mechanically-produced failure. It was also found (66) that the nature of the damage in a highly inert liquid (toluene) and atmosphere (helium) was no different from that observed using water. With regard to cavitation damage in a flowing liquid, Knapp (57) has found that the rate of pitting is highly velocity-dependent, accounted for by the conditions for transport of transient cavities to the specimen. Thus, prediction of the processes in highly corrosive media may be more complicated than appears even now, depending not only on the level of electrochemical activity but also on the details of the flow in the system (62).

Of growing interest are the possibilities for reduction of cavitation damage by cathodic protection, first demonstrated in a controlled experiment by Petracchi (68). Nechleba (69) has reported successful use of the method in hydraulic machinery, and Wheeler (71) has carried out further laboratory experiments to investigate the observed effects. While these investigators associate the mechanism variously with corrosive currents generated in the material by local stress or temperature gradients produced by the cavity collapse forces, such high currents are sometimes needed that protection simply by means of hydrogen bubble formation and "cushioning" suggests itself. The practical consequences of a complete understanding of the phenomenon warrant further, intensive research effort.

OTHER TOPICS; CONCLUDING REMARKS

No specific mention could be made on nonstationary (i.e., time-varying) cavities such as occur in entry of a missile into water, but a good discussion will be found in reference 58. The problem of cavitation noise, which is intimately connected with the collapse of cavities, has been receiving considerable attention, and an excellent analysis and survey has been presented recently by Fitzpatrick and Strasberg (71).

It will be recognized that, in a brief survey of this type, it was possible to give only highlights of progress and problems; more complete discussions of some of the problem areas will be found in references 16 and 62.

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"Letters to the Editor" and "Books Received for Review" appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 629, 630, 636, 648, 667, 681, 699, 754, 756, 760, 763, 782, 797, 807, 817, 826, 834, 872, 873, 875, 879, 881, 893, 922)

Book—610. Borg, S. F., An introduction to matrix tensor methods in theoretical and applied mechanics, Ann Arbor, Mich., J. W. Edwards, Publisher, Inc., 1956, 202 pp. $4.75.

The book under review is based on notes of several graduate and senior elective courses given by the author at Stevens Institute of Technology. It considers briefly such topics as matrix algebra, vector analysis, complex variables, tensors, elasticity theory, theory of plates and shells, boundary-layer theory, theory of plasticity, curvilinear coordinates and tensor analysis as related to dimensional analysis.

Because the author is an engineer and not a mathematician, as stated in the preface, mathematical arguments have been kept to a minimum. Nevertheless, this should be no excuse for stating definitions loosely and theorems incorrectly. For example: on p. 13 in the definition of r, the absolute value sign is superfluous; on p. 15 the theorem given is incorrectly stated; on p. 17 the statement $\partial (iy) = i \partial y$ is unjustified since ∂F is undefined; on p. 44, to say that even for engineering purposes "variation of f" is essentially the same as "differential of f" needs some qualification since, if they were the same essentially, there would be no necessity for using δ in one case and d in another. Figures 6-5 and 8-3 are poorly drawn.

Where applications are concerned, however, author presents his material clearly and carefully. Because of the range of topics covered the student should get an over-all view of the subject of mechanics. The typography is uniformly good.

E. J. Scott, USA

611. Occhini, L., Contribution to Wall's method of separate calculation of the real and imaginary parts of the roots of a polynomial (in German), *ZAMM* **36,** 3/4, 139–145, Mar./Apr. 1956.

Corresponding to n-th degree polynomial $P(x)$ with real coefficients is H, its Hurwitz determinant of n-th order. To $P(x+r)$ corresponds $H(r)$, for any real number r. Author proves $H(r) = 0$ whenever r is the real part of a root of $P(x)$. Thus any real interpolation scheme, such as regula falsi, locates these real parts. For any such r, the highest common factor of $P(x+r)$ and $P(-x+r)$, found by the Euclidean algorithm, is a polynomial the roots of which include all imaginary roots of $P(x+r)$ and so, adding r, all roots of $P(x)$ of real part r. The method seems well adapted to stored-program computers. C. Ablow, USA

Book—612. Tranter, C. J., Integral transforms in mathematical physics, 2nd ed., New York, John Wiley & Sons, Inc.; London, Methuen & Co. Ltd., 1956, xi + 133 pp. $2.

The second edition of this pocket-size monograph, which deals briefly with Laplace, Fourier, Hankel, and Mellin transforms, has been somewhat broadened in scope by inclusion of a chapter on dual integral equations. General nature of the book has not been altered in the new edition; it is not an elementary treatment and it assumes an extensive familiarity with notations, concepts, and procedures of advanced mathematics. Reviewer feels book is suitable as reference or refresher but not as text for first study. Good bibliography and index are helpful. Book is well set up and well printed. L. B. Hedge, USA

613. Wynn, P., Central difference and other forms of the Euler transformation, *Quart. J. Mech. appl. Math.* **9,** part 2, 249–256, June 1956.

614. Yih, C.-S., Solutions of the hyper-Bessel equation, *Quart. appl. Math.* **13,** 4, 462–463, Jan. 1956.

615. Sexl, Th., Systematic integration of the Laplace differential equation (in German), Öst. *Ing.-Arch.* **10,** 2/3, 280–288, 1956.

The fundamental system of solutions is discussed for different values of a parameter. The corresponding asymptotical solutions are given. A. van Heemert, Holland

616. Boley, B. A., A method for the construction of Green's functions, *Quart. appl. Math.* **14,** 3, 249–257, Oct. 1956.

The solution of a two-dimensional elliptic differential equation with given boundary values on a curve C is represented by

$$u(Q) = \int_c u(P)\,[\partial G(Q,P)/\partial n_P]\,ds_P$$

In this $G(P,Q)$ is the Green's function belonging to the given differential equation, which must satisfy the following conditions: (1) $G(P,Q) = 0$ for P on C. (2) for $P = Q$, $G(P,Q)$ exhibits a singularity prescribed by the form of the differential equation. (3) $G(P,Q)$ is a solution of the equation if considered as a function of P. The most difficulties in determining G lie in satisfying the first condition. They can be overcome by splitting up G into a function G_0 which satisfies only conditions 2 and 3, and a function g_0. Since G must satisfy conditions 1, 2, and 3, g_0 has to be an everywhere regular solution of the differential equation if considered as a function of P possessing boundary values which are equal to the negative boundary values of G_0. Therefore, g_0 is given by

$$g_0(P,Q) = -\int_c G_0(R,Q)[\partial G(P,R)/\partial n_R]\,ds_R,$$

according to the aforementioned solution formula. Hence, if a function satisfying conditions 2 and 3 is available, Green's function can be obtained by solving the integral equation

$$G(P,Q) = G_0(P,Q) - \int_c G_0(R,Q)[\partial G(P,R)/\partial n_R]\,ds_R$$

The solution of this equation is given by the Liouville-Neumann expansion which is formed by replacing the function G in the integrand by the right-hand side of the equation and repeating this replacement wherever the function G appears in an integrand.

Then author develops a further, in most cases, faster converging method, in which G is obtained as limit function of a sequence of approximation functions. The first approximation G_1 is yielded by replacing G on the right-hand side of the integral equation with the zero approximation G_0. The function G_1 satisfies conditions 2 and 3 and, therefore, can be used instead of G_0 for the calculation of G. The second approximation is obtained by replacing G on the right-hand side of the integral equation

$$G(P,Q) = G_1(P,Q) - \int_c G_1(R,Q)[\partial G(P,R)/\partial n_R]\,ds_R,$$

and so on. In other words, the direction for the iteration process is given by the formula

$$G_{i+1}(P,Q) = G_i(P,Q) - \int_c G_i(R,Q)[\partial G_i(P,R)/\partial n_R]\,ds_R$$

After using both methods for a problem from the one-dimensional theory of heat conduction, author proves the convergence of the function-sequence G_i in the case of the Helmholtz equation

$$(\partial^2 u/\partial x^2) + (\partial^2 u/\partial y^2) = q(x,y)u\,(x,y)$$

with $q > \sigma$. The method can easily be expanded to multi-dimensional problems. U. Rost, Germany

617. Redheffer, R., On solutions of Riccati's equation as functions of the initial values, *J. rational Mech. Analysis* **5,** 5, 835–848, Sept. 1956.

Author discusses solutions of Riccati's equation $-u_y + a + 2bu + cu^2 = 0$, where $u = u(x, y)$, a, b, and c are functions of y, and the index y indicates differentiating with respect to y. Theory can be applied to transmission through and reflection from a dielectric slab. Author hopefully suggests that the same procedure can be used to discuss more general equations such as $-u_y + a + 3bu + 3cu^2 + du^3 = 0$. D. ter Haar, England

618. Tsien, H. S., The Poincare-Lighthill-Kuo method, pp. 281–349, Advances in Applied Mechanics. Vol. IV (Dryden, H. L., von Karman, T., and Kuerti, G., editors), New York, Academic Press, Inc., 1956.

Lighthill's technique for rendering approximate solutions to physical problems uniformly valid by means of coordinate straining is a significant advance in the treatment of nonlinear differential equations. Present article will be welcomed as a comprehensive survey of the current development of the technique. Framework of article is Lighthill's paper [AMR **3,** Rev. 1829], entire contents of which appear, occasionally abbreviated but more often expanded for pedagogic purposes. Interpolated therein are summaries of subsequent developments: Carrier's boundary-layer method for cases where the technique is inapplicable [AMR **7,** Rev. 2915]; Lin's perturbation method using exact characteristics [AMR **8,** Rev. 71]; Whitham's application to propagation of spherical blast [AMR **4,** Rev. 1248]; and Wu's modification of the technique to treat sink flow of viscous gas [AMR **9,** Rev. 2853].

Last quarter of article is devoted to discussion of apparent failure of technique for elliptic partial differential equations, as exemplified by flow past airfoils, and to detailed exposition of

Kuo's improvement of the boundary-layer solution for incompressible viscous flow past a finite flat plate [AMR **7**, Rev. 3939]. Despite importance of latter work, reviewer hopes (and a number of colleagues concur) that the method will continue to be known simply as "Lighthill's technique."

M. D. Van Dyke, USA

Book—619. Canning, R. G., Electronic data processing for business and industry, New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, xi + 332 pp.

The objective of this book, as stated by the author, is to outline a program of study and planning leading to the preparation of a proposal to top management for the installation of data-processing equipment. It does a commendable job.

The book is directed to the person who would be making the study and doing the planning. No previous knowledge of electronics is required of the reader; hence, to a computer engineer, the technical aspects would be rather basic. To a business man and others interested in business applications of computers, however, the book can be of considerable help.

All through the book, author emphasizes the system engineering approach to the problem; that is, to plan for a processing center which meets the over-all needs of a company or department, and not the planning for a faster, more accurate, method of handling a presently inefficient procedure. The major subjects included are flow diagramming, clerical operations, design of the processing system, examples of programming electronic computers, and a broad summary of the characteristics of available equipment.

A short chapter describes the role of operations research to the program.

L. D. Findley, USA

620. Bolles, E. E., and Engel, H. L., Basic digital series. Part 9. Control elements in the computer, *Control Engng.* **3,** 8, 93–98, Aug. 1956.

621. Rubinoff, M., and Beter, R. H., Basic digital series. Part 10. Input and output equipment, *Control Engng.* **3,** 11, 115–123, Nov. 1956.

622. Adams, D. P., Alignment diagrams from network charts by graphics, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-39, 5 pp. + 7 figs.

Alignment diagrams can be constructed accurately from mathematical or empirical network charts by a graphical process requiring no knowledge of nomography. Savings in skill and time this way enhance the natural value of the alignment diagram. An exact graphical method is described which is quick, uniform, and as accurate as the plotted network chart and drafting warrant.

From author's summary

623. Levens, A. S., Graphical integration by pole-and-ray, *Control Engng.* **2,** 8, p. 71, Aug. 1955.

624. Brower, W. B., Jr., The application of the electric-tank analogy to two and three-dimensional problems in linearized aerodynamic theory, Rensselaer Polytech. Inst. (Research Division) TR AE5506, 103 pp., Dec. 1955.

Author presents the pertinent aerodynamic theory and the details of construction, operation, and use of an inexpensive, easily-constructed rapidly-used electrolytic "deep-tank" analog lifting-surface computer for solution of the integral equation characterizing two- and three-dimensional linearized lifting theory. The practicality and the advantages and limitations of use are shown by comparison of analogic solutions of velocity potential with corresponding theoretical solutions for four two-dimensional and four three-dimensional problems. The computer has possibilities for yet other studies: indicial lift, reverse flow, wing-body interference, etc.

T. J. Higgins, USA

625. Brower, W. B., Jr., and DeRienzo, P., The design of a basic electric-tank analogy installation, Rensselaer Polytech. Inst. Aero. Engng. AF 18 (600)-499, 9 pp., Sept. 1955.

The application of electric analog techniques using electrolytic tanks is discussed in two reports (see preceding review) which are outgrowths of the studies of the first author during a period spent at the Laboratoire de Calculs Analogies, Institut Blaise Pascal, Centre National de la Recherche Scientifique, Chatillon sous Bagneux, France. The special equipment developed by this laboratory for the solution of problems by electrolytic-tank analog procedures has been both redesigned to American specifications and modified to include a number of improvements and revisions. A detailed description of the mechanical and electrical aspects of this equipment (supported by several photographs and schematic drawings), as recently installed at Rensselaer Polytechnic Institute, is given. Copies of working drawings are available on request.

T. J. Higgins, USA

Mechanics (Dynamics, Statics, Kinematics)

(See Revs. 627, 632, 729, 731, 827, 829, 883, 884, 935)

Servomechanisms, Governors, Gyroscopics

(See also Revs. 620, 820, 834)

626. Herschel, R., A general quadratic optimum (in German), *Regelungstech.* **4,** 8, 190–195, 1956.

The state of a controlled system is assumed to be completely determined by a given finite set of variables. Let V be an arbitrary positive definite quadratic form in these variables, such as the square of the error.

With Feldbaum, author considers the system to be optimum when the time integral I of V from zero to infinity is a minimum. From V, author constructs a new quadratic form W so that I is the initial value of W. The minimizing problem is reduced to a study of W, which can often be readily treated.

R. Oldenburger, USA

627. Herschel, R., Application of the generalized quadratic optimum (in German), *Regelungstech.* **4,** 9, 229–233, 1956.

The optimum criterion of Feldbaum involving positive definite quadratic forms is applied to third-order processes with proportional or proportional plus integral controllers. These applications show how optimum parameters are chosen in numerically defined cases.

R. Oldenburger, USA

628. Schunck, T. E., Variation of the first Lüthi criterion for prescribed minimum damping (in German), *Regelungstech.* **4,** 8, 198–199, 1956.

Author re-derives Lüthi criterion, by which one may determine, from mapping a certain boundary in the complex plane, whether the damping of a linear system exceeds a prescribed minimum. Criterion is not practical, as stated, for cases where at least one characteristic root (unknown) lies outside the test boundary. Author proposes and proves a supplementary criterion which circumvents this difficulty by a modified mapping process. This method is also useful for finding boundaries for the complex roots of high-order algebraic equations.

G. A. Nothmann, USA

629. Fel'dbaum, A. A., Synthesis of optimal systems by means of phase spaces (in Russian), *Avtomatika i Telemekhanika* **16,** 2, 129–149, 1955.

Utilizing his own method of n intervals, author develops the method of the synthesis of optimal automatic-control systems. While the process of the synthesis is associated with the examination of the trajectories character in the phase space of the system, author determines, in the space of n dimensions, the hypersurface (S) of $n-1$ dimensions, which is the boundary between the two regions characterized by the values $\sigma = \pm 1$, when the restriction of the regulating quantity is of the form

$$|a_0\, d^n X_t + a_1\, d^{n-1} X_t + \cdots + a_n X_n| = v \leq M_n,\ d = d/dt,\ a_0 \neq 0,$$

where $v = \sigma M_n$ in the optimal process. By means of S, the block diagrams of the systems may be determined. One obtains the class of the functions X_0 for which S is stationary or quasistationary.

The examples of the synthesis which can be solved in the phase plane (when the input quantity is restricted by the modulus – the case of the system with two inertia elements coupled in series, or one inertia and other integral element in series) or in the space in three dimensions (with restriction $X_{ttt} \leq M$) are discussed.

It is indicated that the approximation of the equation of S by means of simple functions gives the plain system very near to the optimal one. The method of the synthesis can be used as the basis of the model for the automatic synthesis mechanism.

D. Rasković, Yugoslavia

630. Andre, J., and Seibert, P., Piecewise linear differential equations which occur in automatic control processes, Part II (in German), *Arch. Math.* **7**, 3, 157–164, 1956.

631. Maker, P., and Dix, E. L., How to apply closed loop hydraulics to machine tools, *Appl. Hydraulics* **9**, 10, 76–81, Oct. 1956.

632. Kane, T. R., An approximate solution of the equations of motion of a gyroscope, Proc. second Midwestern Conf. solid Mech. Purdue Univ., Sept. 1955, 60–67.

An approximate solution for the equations of motion of an idealized gyroscope is obtained by postulating the form of the solution in a manner consistent with experimental observations and then using the equations to arrive at a detailed description of the motion. It is shown that if the outer gimbal ring is forced to perform an oscillatory motion of small amplitude, the inner gimbal ring will rotate with an essentially constant angular velocity.

A. I. van de Vooren, Holland

Vibrations, Balancing

(See also Revs. 830, 935)

Book—633. Wilson, W. K., Practical solution of torsional vibration problems, Vol. I. Frequency calculations, 3rd ed., New York, John Wiley & Sons, Inc., 1956, xxxii + 704 pp. $16.

An impressive amount of experience in torsional vibration problems has been compiled in this book, which in its third revised edition contains many additions, particularly in the sections dealing with geared systems and systems containing distributed masses. The complete work remains in two volumes, but the text has been rearranged so that each volume is now self contained in the sense that each deals with a particular aspect of the subject. Volume I contains frequency calculations and analyses of the characteristics of different types of oscillating systems.

The numerical method for calculating natural frequencies and natural modes is the frequency tabulation method, an extension due to Gümbel and others of the torque summation method. The mathematics of the book is understandable for any reader who is acquainted with simple algebraics. Though this may be an advantage in making the book accessible to all practicing engineers, reviewer considers it as a drawback that none of the powerful matrix methods are mentioned. No attention has been paid to the advent of electronic computers, which make the use of matrix calculus imperative in connection with the calculation of influence coefficients and of natural modes and frequencies with corresponding generalized masses.

Reviewer believes that the value of this book as a textbook would have been increased if the frequency tabulation method for complicated systems had been replaced by the analytical methods, based upon orthogonality relations between natural modes, which lead to a systematic computation of all natural modes and frequencies of interest by matrix iteration. Nevertheless, this third edition will prove its value by the many excellent expositions of torsional vibration problems in mechanical, marine, aeronautical, and electrical engineering. It is divided into the following chapters: I Simple systems; II Frequency tabulations; III Multimass systems; IV Simple geared systems; V More complicated geared systems; VI Coupling effects in geared systems; VII Effective inertia method-Concentrated mass systems; VIII Effective inertia method-Distributed mass systems; IX Coupled torsional and flexural vibration in engine systems; X Equivalent masses; XI Equivalent shafts; XII Official requirements relating to vibration. The book concludes with a carefully composed and very extensive bibliography and index.

Designers will find the book a fruitful reference work.

J. F. Besseling, Holland

634. Lo, H., and Goulard, M., Torsion with warping restraint from Hamilton's principle, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955, 68–80.

Authors consider a thin-walled cantilever tube with double-symmetrical cross section constant along its axis and maintained shape. Therefore deformation is defined by a rigid body rotation around axis and a warping displacement; later it is given in series form of products of known circumferential coordinate functions and unknown functions of length coordinate and time. Using Hamilton's principle and restricting to the first series term yields a general equation of rotation only.

Examples treat rectangular tubes under concentrated and distributed torques; in diagrams, results are compared with those gotten by neglecting warping restraint and, in the special case of a torque at the free end, also with the exact solution requiring much work. The last example deals with torsional vibration of a tube and corrections to the lowest eigenfrequency solutions gotten by suppressing warping restraint.

W. Mudrak, Austria

635. Bishop, R. E. D., and Johnson, D. C., Some properties of nodes in vibrating systems, *Aero. Quart.* **6**, 1, 46–58, Feb. 1955.

Sequel to a paper by the first author [AMR 8, Rev. 1280]. If rigid disks are attached to an elastic shaft, a harmonic torque T applied to number r gives to number s a harmonic motion proportional to T; the ratio α_{rs} is the "cross receptance" between the two disks; it depends on the frequency ω. In several simple torsional systems it is a fraction, the denominator and the numerator being polynomials in ω^2; the latter is the same for all mutual receptances, and its zeros are the natural frequencies of the system. Receptance diagrams (α_{rr}, ω) and ($1/\alpha_{rr}$, ω) are given and shown to indicate the existence of nodes: some disk do not move in a particular principal node. The theory may be extended to any type of vibrating system and any set of generalized coordinates.

O. Bottema, Holland

636. Hahn, W., Stability of nonlinear systems (in German), *ZAMM* **35**, 12, 459–462, Dec. 1955.

The motion of a physical system of nth order may be described by

$$x_i(t) = X_i(x_1, x_2, \cdots\cdots x_n) \qquad i = 1 \cdots n \qquad [1]$$

Eqs. [1] are supposed to permit the "trivial" solution

$$x_1 = x_2 = \cdots = x_n = 0. \qquad [2]$$

Liapunov stated that the asymptotic stability of [2] [$\lim x_i = 0$ for $t \to \infty$] is determined by the linear terms of X_i in [1].

This statement can be refined. Following Malkin, author states that asymptotic stability is assured if the nonlinear parts X_i^*, in X_i of [1] are bounded by

$$|X_i^*(x_1 \cdots x_n)| < b(|x_1| + |x_2| + \cdots + |x_n|) \qquad [3]$$

with b depending on the coefficients of the linear terms. Special cases have been treated by Malkin and Ajzerman. Author gives an outline for the treatment of the general case. The presentation allows to appraise the amount of computing work necessary for carrying out the individual steps. K. Klotter, USA

637. Johnson, D. C., and Bishop, R. E. D., The modes of vibration of a certain system having a number of equal frequencies, *J. appl. Mech.* **23,** 3, 379–384, Sept. 1956.

This paper is concerned with a conservative system, which represents an idealized bladed rotor, whose principal modes are indeterminate. The dynamical behavior of the system is discussed and a method of selecting suitable principal modes and coordinates is explained.

From authors' summary by M. Botman, Canada

638. Bartunek, P. F., Some interesting cases of vibrating systems, *Amer. J. Phys.* **24,** 5, 369–373, May 1956.

Three simple vibrating systems are described: The bifilar and trifilar pendula and the meter stick rocking on a cylindrical surface. All types afford challenging analytical problems. The bifilar pendulum with adjustable height of bob gives practice in scientific judgment, for, of three possible modes of oscillation, one is definitely best if one be interested in determination of **g**. The dumbbell model of bifilar pendulum, as well as the rocking stick, offers opportunities to study the effect of separately changing inertia and restoring factors. The trifilar pendulum offers an alternate to other common methods of measuring moments of inertia. From author's summary

639. Cox, H. L., and Klein, B., Vibration of isosceles triangular plates having the base clamped and other edges simply-supported, *Aero. Quart.* **7,** 3, 221–224, Aug. 1956.

640. Shibaoka, Y., On the transverse vibration of an elliptic plate with clamped edge, *J. phys. Soc. Japan* **11,** 7, 797–803, July 1956.

An exact solution is determined for the fundamental normal mode of transverse vibration of an elliptic plate clamped at its edge. From numerical calculations of the fundamental frequency for three values of eccentricity of the elliptic plate, the relationship between fundamental frequency and eccentricity is shown graphically. An approximate formula expressing this relationship, to be used in cases of small eccentricity, is derived.

J. C. Truman, USA

641. Shioiri, J., and Shibata, S., On the vibration of gas turbine blades (in Japanese), *J. mech. Lab. Japan* **1,** 2, 37–41, 1955.

Experimental studies on the flutter of accelerating cascade are presented, and Shioiri's theory, that pure bending flutter can occur in the accelerating cascade without stall, has been ascertained. In the present experiment, the circular cascade, composed of n blades, is replaced by a linear cascade, composed of $n + 1$ blades, and the two blades located at both ends of the linear cascade are linked together so that the coupling condition of both cascades may be the same. The profile of the blade used is NACA 6409.

The critical velocity and the mode of flutter are expressed as functions of incidence angle, stagger angle and pitch-by-chord ratio being the parameters. In general, with the increase in incidence, the critical velocity decreases at first, then increases and reaches the maximum point, then decreases again. In the region of the incidence smaller than that of the maximum point, no stall occurs. This is the region of the pure bending flutter, which has been assumed by the author. In the region of the incidence larger than that of the maximum point, stall flutter occurs.

M. Yamanouchi, Japan

642. Mottard, E. J., Preliminary investigation of self-excited vibrations of single planing surfaces, *NACA TN* 3698, 19 pp., June 1956.

A preliminary investigation was made of self-excited vibrations of single planing surfaces. A self-excited oscillation requiring freedom in rise but not in trim occurred with high aspect ratio (order of 10) of the wetted portion. This vibration could be controlled most successfully by methods (such as the use of dead rise) which limited the wetted aspect ratio.

From author's summary

643. Chakravorty, J. G., Vibrations of spherically aeolotropic shell, *Bull. Calcutta math. Soc.* **47,** 4, 235–238, Dec. 1955.

Mathematical theory of (1) radial vibration and (2) rotatory vibration of a thick spherical shell of spherically aeolotropic material is presented. Author obtains equations which determine the natural resonance frequencies, and expressions for the displacement, stress components, and strain components.

R. L. Woolley, Iraq

644. Carver, D. R., Extensional vibrations of rings, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955, 229–235.

Author treats in-plane ring vibration, including bending-extensional coupling resulting from curved-beam theory (Winkler). Neglecting rotatory inertia and shear deformation he finds little variation from their ring results for a very thick ring, $r_2/r_1 = 2$. Reviewer feels rotatory inertia and shear are probably more important than terms considered. R. Plunkett, USA

645. Stephenson, C. V., Higher modes of radial vibrations in short, hollow cylinders of barium titanate, *J. acoust. Soc. Amer.* **28,** 5, 928–929, Sept. 1956.

Paper discusses the forbidden and allowed modes of radial vibrations in hollow cylinders of barium titanate. Resonant frequencies for first three modes of elements with a given ratio of outside diameter to inside diameter (8.30, 2.85, and 2.13) have been calculated and are found to be in agreement with measured values within the limits of the experiment.

G. S. Verma, India

646. Morrow, C. T., and Sargeant, H. I., Sawtooth shock as a component test, *J. acoust. Soc. Amer.* **28,** 5, 959–965, Sept. 1956.

The shock effect of a terminal-peak sawtooth of acceleration obtained by a drop onto a lead pellet has been investigated experimentally using the shock spectrum as the criterion of severity. It is shown that this spectrum obtained by analysis of the acceleration-time data can be made to approximate closely over a wide frequency range that obtained theoretically for an ideal sawtooth. The smoothness of the spectrum which results from the extreme asymmetry of the pulse shape makes the sawtooth a particularly attractive standard pulse shape for shock test in the laboratory.

From authors' summary by B. E. Gatewood, USA

647. Rautu, S., Calculation of vibration of frames, with successive approximation (in Rumanian), *Acad. Repub. pop. Rom. Comun.* **6,** 2, 291–295, 1956.

Wave Motion in Solids, Impact

(See also Revs. 646, 758, 909, 914, 932, 934)

Book—648. Borkmann, K., and Oberlander, S., Solution of the general boundary-value problem for one-dimensional damped waves with harmonic time relation [Lösung des allgemeinen Randwert-problems für eindimensionale gedamfte Wellen bei harmonischem Zeitgesetz], Berlin, Akademie-Verlag, 1955, 98 pp. DM 12.

Authors examine the real hyperbolic differential equation $(\partial^2 u/\partial x^2) - A(\partial^2 u/\partial t^2) = D(\partial u/\partial t)$; A, D, constants, with $A \geqslant 0$, with prescribed boundary conditions along two boundaries, $x = x_i (i = 1,2)$, of the form $a_i u(x_i) + b_i(\partial u/\partial x)_{x=x_i} = c_i \cos \omega t + s_i \sin \omega t$, the solution to be harmonic in t with preassigned frequency, ω. Their study is theoretical, but exhaustive and practically convenient for numerical work, although rather pedestrian. Ample tables (55 pages) to five significant digits, and three pages of simple but useful formulas are appended. The theory is stated to be immediately applicable to certain hydrodynamic and certain electrotechnical problems to which references are made, but which are not here investigated. Authors point out that while the equation may be transformed to $\partial^2 v/\partial \xi^2 = p(\partial^2 v/\partial t^2 + \partial v/\partial t)$, the transformation becomes impractical for A small.

A. A. Bennett, USA

649. White, J. E., and Frost, H. H., Unexpected waves observed in fluid-filled bore holes, *J. acoust. Soc. Amer.* **28,** 5, 924–927, Sept. 1956.

In seismic prospecting operations, apparently anomalous impulses are sometimes observed in bore holes. Explanations for four of these are advanced. The first is a flat-topped pulse generated when a slug of water rejoins the main column after separating from it, following an explosion in the hole. The second is a negative pressure pulse in a cased hole caused by radial expansion of the casing as a longitudinal wave travels down it. The third is a pressure decrease at the bottom of a hole when a compressional wave is incident from above. This results from downward motion of the hole bottom. The fourth is reversed (upward) polarity of initial particle motion of the fluid at the interface between a limestone over a shale, which is attributed to the greater radial compression of the less rigid shale.

F. G. Blake, Jr., USA

650. Homma, S., Boundary waves of longitudinal type along a continuously varying intermediate layer, *Geophys. Mag., Tokyo* **27,** 1, 35–59, Jan. 1956.

Approximate investigation of plane, longitudinal waves traveling in an infinite medium having a layer with smoothly varying properties rather than a uniform layer which introduces sharp discontinuities in physical properties at the two interfaces. Analysis indicates that for medium having uniform elastic properties but density varying as $\rho(1 - \delta \exp(-\sigma^2 z^2))$ longitudinal waves may propagate essentially along the layer. G. W. Housner, USA

651. Pukl, S., Dynamic loads with special consideration of impact. Parts I, II (in Serbian), *Naše Gradevinarstvo, Beograd* **10,** 3, 359–363, Mar. 1956; **10,** 4, 505–509, Apr. 1956.

Structures under dynamic loads and impact mass and time must be considered. Author discusses mathematical methods already known, and points out that physical phenomena at the point of application of kinetic energy must also be considered in calculating the balance of energy. Two cases are investigated with mathematical presentation: (1) Cases in which nearly the whole kinetic energy due to the dynamic loading is transformed into deformations or oscillations of the structure; (2) cases in which only local deformations or failure at the point of application result. Equations for both cases are derived and criterion presented for speedy classification of the proper case and simplified solution. References: Timoshenko, Karas, and Weyrich.

J. J. Polivka, USA

652. Cristescu, N., Some observations on the two-dimensional stresses in axial symmetrical dynamical problems of plasticity [Theory Prandtl-Reuss] (in Rumanian), *Acad. Repub. pop. Rom. Comun.* **6,** 1, 19–28, 1956.

In studying the title problem, two types of longitudinal cylindrical waves are obtained upon applying the theory of Prandtl-Reuss. On the two waves there are discontinuities of the derivatives of U_r and σ_r, as well as of the derivatives of U_θ and $\tau_{r\theta}$. On the wave of type I, which is propagated more rapidly, the discontinuities of U_r and σ_r are preponderant over those of U_θ and $\tau_{r\theta}$. On the wave of type II the situation is the reverse.

If one of the components of the displacement can be neglected, a single type of wave remains propagated; on it remains only those discontinuities which were preponderant on the corresponding wave of the general case. The other type of wave degenerates into a fixed discontinuity.

From author's summary by L. Malvern, USA

653. Plass, N. J., Jr., Theory of plastic bending waves in a beam of strain-rate material, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955, 109–134.

Author develops a theory for bending waves in a beam that is analogous to that contributed by Malvern for plastic longitudinal waves in a bar [AMR **4,** Revs. 2372, 4088]; a linear strain-rate law is employed for both the bending and shear stress. Approximate stress equations of motion are used in the theory which the author obtains from the exact equations with the aid of the Timoshenko bending mechanism. Hence, the effects of shear and rotatory inertia in the beam are considered. The resultant theory is contained in a sixth-order system of linear partial differential equations.

Author uses the method of characteristics to solve numerically two problems involving the semi-infinite beam: (a) end subjected to a step moment and (b) to a step angular velocity. Both cases exhibit a plastic region just behind the leading wave front (which travels with the elastic "bar" velocity) and at the end section, the latter spreading with time for the case of step angular velocity. Moment-distance curves (at fixed time values) for the two solutions are compared. J. Miklowitz, USA

Elasticity Theory

(See also Revs. 665, 672, 674, 678, 693, 696, 698, 700, 717, 94

654. Eubanks, R. A., and Sternberg, E., On the completeness of the Boussinesq-Papkovich stress functions, *J. rational Mech. Analysis* **5,** 5, 735–746, Sept. 1956.

The displacement, in the linear theory of isotropic elasticity, may be expressed in terms of the four Boussinesq-Papkovich functions. The authors investigate the completeness of this representation in the absence of body forces. They also exhibit a variety of cases in which completeness is or is not lost by taking one or more of the functions as zero. R. D. Mindlin, USA

655. Budiansky, B., and Pearson, C. E., A note on the decomposition of stress and strain tensors, *Quart. appl. Math.* **14,** 3, 327–328 (Notes), Oct. 1956.

Two theorems are derived on the decomposition of stress-strain fields into two parts. One satisfies certain prescribed conditions on a part of the boundary surface and the other satisfies different conditions on the remainder of the surface. It is stated that the theorems are analogous to the solenoidal parts. The analogy

seems rather remote and it would be useful to be told the purpose and application of the theorems. W. M. Shepherd, England

656. Frederick, D., Physical interpretation of physical components of stress and strain, *Quart. appl. Math.* **14,** 3, 323-327 (Notes), Oct. 1956.

Paper gives a physical interpretation of several different sets of physical components of stress used by different authors and of some new sets and concludes that for stress (strain) there are eight (two) sets of physical components which might be used for solving boundary-value problems in elasticity involving general coordinates. W. M. Shepherd, England

657. Chakravorty, J. G., Some problems of plane strain in a cylindrically aeolotropic cylinder, *Bull. Calcutta math. Soc.* **47,** 4, 231-234, Dec. 1955.

By considering a problem of plane strain author overcomes difficulties encountered by Carrier [*Trans. ASME* **65,** A-117, 1943] in plane stress problem. He solves the following problems for hollow circular cylinder: (1) rotation about its axis; (2) stretching in the direction of the axis; (3) initial stresses due to a radial fissure.
G. A. Zizicas, USA

658. Stowell, E. Z., and Pride, R. A., Poisson's ratios and volume changes for plastically orthotropic material, *NACA TN* 3736, 28 pp., Aug. 1956.

Measurements of Poisson's ratios in three orthogonal directions on aluminum alloys and stainless steel show no permanent plastic change in volume. A method is suggested for effecting a correlation between the measured values of Poisson's ratios and the stress-strain curves; of the latter, the difference in tension and compression has a significant effect. F. E. Borgnis, USA

659. Levy, S., Thermal stresses and deformations in beams, *Aero. Engng. Rev.* **15,** 10, 62-70, Oct. 1956.

Author develops a simplified theory to allow the estimation of stresses and curvatures due to aerodynamic heating of typical airplane beam sections. Initially he demonstrates that the stresses and curvatures resulting from the assumption of either "step" or "ramp" temperature distributions are similar for the same value of total heat stored. Both rectangular solid and rectangular box beams are considered in detail.

Heat transfer from the air into the beam is then considered, and a simplified theory is developed, including the effect of the blanket of surface air and of lateral heat flow into the webs of the box beam. A numerical example is given, including typical values for the heat-transfer coefficient of the surface air, and showing how the temperature, stresses, and curvature vary for different assumed values of this heat-transfer coefficient.

Author concludes that stress and curvature depend primarily on total heat stored, that cross-sectional shape has a significant effect on stress induced by a given temperature distribution, and that changes in the surface air heat-transfer coefficient have only a small effect on the stresses and curvature induced.
J. M. Alexander, England

660. Barriage, J. B., and Durelli, A. J., Application of a new deformeter to two-dimensional thermal stress problems, *Proc. Soc. exp. Stress Anal.* **13,** 2, 97-106, 1956.

Displacing the sides of a slit made in the photoelastic model of a multiply connected cylinder will produce isochromatic and isoclinic patterns corresponding to thermal stress distribution. Biot's mechanical analogy of thermal loading for multiply connected regions permits evaluation of displacements and rotation in error for given steady-state heat flow conditions. New deformeter is described allowing, like Weibels, continuous variation of displacement. Several deformeters can be used simultaneously because instrument is smaller than Weibel's. New technique was used for ring, and solution agreed to 9% with theoretical solution. Six deformeters were applied to case of more complicated multiply connected shape. R. Weck, England

661. Chmelka, F., Thermal stresses in a Prandtl-Reuss body (in German), *Öst. Ing.-Arch.* **10,** 2/3, 133-140, 1956.

Prandtl-Reuss equations for an ideal plastic body are extended to cover the case of expansion due to a temperature field. Application of the theory is demonstrated by a simple example.
From author's summary by J. Solvey, Australia

662. Horvay, G., Stress relief obtainable in sectioned heat generating cylinders, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955, 45-59.

The thermal stresses in a solid, heat-generating cylinder of finite length are compared with those resulting from sectioning the cylinder into six equal sectors. The sectors are considered unconstrained, but are assumed to remain closely packed so that the temperature distribution is the same (parabolic) as in the solid cylinder. An approximate analysis, in which author's previous work on the end problem of rectangular strips is utilized to supply an indication of the nature of the stress distribution in the cylinder, indicates that sectioning reduces the stresses to about 40% of their original magnitude. J. H. Weiner, USA

663. Tolstoy, I., Dispersive properties of a fluid layer overlying a semi-infinite elastic solid, *Bull. seism. Soc. Amer.* **44,** 3, 493-512, July 1954.

Experimental Stress Analysis

(See also Revs. 645, 660, 703, 725, 949)

664. Long, H. F., Experimental stress analysis using the "moiré" effect (in Spanish), *Ciencia Tecn.* **121,** 610, 53-59, June 1956.

Method described has been successfully used to measure strains of 10^{-3} or 10^{-4} and seems to be very valuable in the experimental study of plasticity problems. Author presents the fundamentals of the method, its advantages, and suggests a photographic operating procedure.

There are difficulties in the way of increasing the precision so as to satisfy the needs of current elastic problems. Author says that methods to obtain such a precision are being tried.
J. F. Borges, Portugal

665. Guerra, G., The Ricci analogy, and the experimental stress analysis of elastic frames (in Italian), *Aerotecnica* **35,** 1, 11-16, Feb. 1955.

Two analogies between forces and deflections in structures loaded in their own plane and normal to it are treated. The first one, from W. Prager [*Quart. appl. Mech.* Mar. 1946], is described briefly and a general example is given. The second one, developed by the author, is based on C. L. Ricci's theory [*Accad. delle Sci.*, Torino, 1911]. The new analogy is useful for any plane structure and has not the limitation of the first one in cases of more than three bars joining at a node.
L. J. Piatti, Argentina

666. Jeske, O., Improvement of the evaluation method of Frocht in photoelasticity (in German), *Bautechnik* **33,** 4, 128-131, Apr. 1956.

It is shown that the method of shear stress difference in the calculation of plane strain situations in photoelasticity in those places where the isochromatics or isoclines are densely grooved,

requires subdivision into smaller parts. The accuracy of this calculation is shown and proved on an example for eccentrically loaded spring link. L. Föppl, Germany

667. Curtis, A. J., and Richart, F. E., Jr., Photoelastic analogy for non-homogeneous foundations, *Trans. Amer. Soc. Civ. Engrs.* **120,** 35-53, 1955.

It is shown that the stresses in a state of plane strain or generalized plane stress in an isotropic, elastic body, whose modulus of rigidity varies along a direction in the plane, satisfy differential equations of the same form as those which are satisfied by the stresses in an elastically homogeneous free slice whose thickness varies (moderately) according to the same law as that which governs the variation of modulus. As an application, the results of photoelastic measurements of stresses in a wedge of linearly varying thickness under a localized edge load are compared with (1) theoretical values for linearly varying modulus, (2) theoretical values for the homogeneous wedge, and (3) photoelastic and theoretical values for the homogeneous plate of uniform thickness. In general, the tests confirm the analogy within a few per cent.
R. D. Mindlin, USA

668. Bell, J. F., Determination of dynamic plastic strain through the use of diffraction gratings, *J. appl. Phys.* **27,** 10, 1109-1113, Oct. 1956.

Paper presents a method for the measurement of plastic strain in solids; the method is applicable either to dynamic or static determinations. Gage lengths of a few thousandths of an inch have been used in measuring plastic wave propagation for strains up to 8%. The strain is determined by measuring the angle of diffraction of a grating on the specimen surface.

Using this diffraction grating technique, it has been possible to make dynamic measurements of large strain with a gage length of 1/32 in. or less. Simultaneous measurements of strain, displacement, and slope of surface have been made for metals subject to high rates of strain. R. K. Bernhard, USA

669. Cooke, R. W., and Seddon, A. E., The laboratory use of bonded-wire electrical-resistance strain gauges on concrete at the Building Research Station, *Mag. Concr. Res.* **8,** 22, 31-38, Mar. 1956.

A description is given of methods and experience of using bonded-wire electrical-resistance strain gages on concrete, mainly in short-term static loading tests. Precautions required to obtain reliable strain data and the accuracy of surface strain measurement are discussed on the basis of tests and experience, and the merits of mounting the gages on brass foil are considered. Some information is also included on the questions of a suitable gage length and the long-term instability of the gages on concrete.
From authors' summary

670. Fraser, A. F., Experimental investigation of the strength of multiweb beams with corrugated webs, *NACA TN* 3801, 17 pp., Oct. 1956.

The results of an experimental investigation of the strength of multiweb beams with corrugated webs are reported. Included in the investigation were two types of connection between the web and the skin. A comparison between the structural efficiency of corrugated-web and channel-web multiweb beams is presented, and it is shown that, for a considerable range of the structural index, corrugated-web beams can be built which are structurally more efficient than channel-web beams. From author's summary

671. Bramall, B., Resonance stress testing, *Engineer, Lond.* **202,** 5247, 224-228, Aug. 1956.

Author proposes transverse natural frequency test to experimentally determine axial loading in a structural member. Chief application would be to members of frames which are statically indeterminate or contain high initial stresses, e.g., from dead loading. Influence of end fixity is pointed out, and procedure is developed for taking this into account through auxiliary measurement of relative curvature, by the use of wire strain gages, at three stations along the member. Stations selected are the midpoint and two quarter points. C. W. Gadd, USA

Rods, Beams, Cables, Machine Elements

(See also Revs. 644, 657, 659, 670, 671, 695, 710, 715)

672. Trenks, K., Infinitely long beam on normal and rotational elastic supports (in German), *Bauingenieur* **31,** 7, 237-245, July 1956.

Cases of infinite and semi-infinite beams supported by discrete linear springs offering elastic support to both normal deflection and angular rotation are considered. The supports are assumed to be equally spaced and all have identical elastic characteristics. The beam is cut midway between supports and the transverse shears and bending moments are regarded as unknowns. Systems of linear algebraic equations are formulated for the shears, the equations being infinite in number and each equation containing at most five unknowns. Analogous equations are presented for the bending moments. Influence lines are presented for the reactions due to a force acting normal to the beam as well as an applied moment. The analogous case of finite length beams has been discussed by Klitchieff [AMR, **4** Rev. 2404; **5,** Rev. 1338], but references to this as well as other pertinent treatments of beams on elastic foundations are lacking. W. A. Nash, USA

673. Strauss, M. W., Design constants for beams of variable section, *J. Amer. Concr. Inst.* **27,** 8, 839-849, Apr. 1956.

Author discusses problem of moment distribution for beams of nonuniform cross section. For such a case author utilizes numerical integration to determine carry-over factors, fixed-end moments and relative stiffness.

Although paper gives nothing new as regards theory, reviewer believes results presented may be of aid in detail calculations of structural design. W. J. Carter, USA

674. Berger, E. R., Variational principles of elastostatics in the theory of the second order (in German), *Öst. Ing.-Arch.* **10,** 2/3, 124-129, 1956.

After a brief discussion of well-known variational principles in elastostatics—minimum potential energy (Dirichlet) and minimum complementary energy (Menabrea)—author points out that although the principle of minimum energy carries over to the second-order theory and consequently so does Castigliano's theorem, the method of complementary energy in its present existing form does not. However, according to a theorem of K. Friedricks, a conjugate extremal principle must exist.

Author derives it for the case of the bending and axial loading of a straight beam. An example involving stresses due to temperature changes is given. E. Saibel, USA

675. Volterra, E., and Chung, R., Constrained circular beams on elastic foundations, *Trans. Amer. Soc. civ. Engrs.* **120,** 301-310, 1955.

Authors give explicit solution for circular beam on elastic foundation symmetrically loaded by equally spaced rigid columns which prevent rotation of beam at column feet.

Tables of results to six places are given for 3, 4, 6, 8, and 12 columns. Only two values each of relative torsional-transverse stiffness and relative foundation stiffness are given, so that they are of limited application for design.

Assumptions necessarily made in analysis do not justify six-place accuracy. Computations are laborious; however, reviewer would like to see results to two or three places only, but for a wider range of stiffness ratios.

In a worked example with 8 columns and fairly soft foundation, deflection and therefore foundation pressure vary less than 4% along beam, so that assumption of uniform foundation pressure would be adequate for design. Still simpler treatment as uniformly loaded straight fixed-end beam of length $\pi R/4$ gives end and center moments within about 2%. Torsional moments are less than 8% of maximum bending moment.

Printing errors noted are "gamma" instead of "nu" at beginning of tables and in worked example. In table 3, 6th entry in 6th column should probably be 0.067053. A. Burn, Australia

676. Spangler, M. G., Stresses in pressure pipelines and protective casing pipes, *Proc. Amer. Soc. civ. Engrs.* **82,** ST 5 (J. Struct. Div.), Pap. 1054, 33 pp., Sept. 1956.

Paper analyses stresses in buried pipelines and deflections of casing pipes, making use of Marston's theory of loads on underground conduits, Boussinesq's solution for a point load on the surface of a semi-infinite elastic solid, and the theory of thin rings. Specific numerical examples of the analysis are given.
H. D. Conway, USA

677. Shiratori, E., and Sakaki, S., Strength of high-speed rotating disks (in Japanese), *Trans. Japan Soc. mech. Engrs.* **21,** 103, 181–186, Mar. 1955; **21,** 111, 780–785, Nov. 1955; **22,** 119, 475–479, July 1956.

Results of plastic deformation and bursting tests for high-speed rotation of aluminum and brass disks of uniform thickness are described. Distributions of radial displacements, variations of thickness and Vickers hardness on radial lines are measured at various speeds. Also bursting speeds and bursting behavior are observed. From the observed data, strains in tangential, radial, and axial directions are calculated, and the relations among the strains, hardness, and the speed of revolutions are analyzed.

A method of determining stresses and strains in a fully plastic rotating disk of uniform thickness containing a central hole is developed by means of the deformation theory, assuming (1) that during plastic deformation, the material is homogeneous and isotropic, (2) volumetric strain is zero, (3) Mises' criterion is satisfied, and (4) neglecting all elastic strains and axial stress.

Comparisons between calculated values and experimental data of strain distributions show that the calculated values of radial deformations are somewhat lower than the observed values. The authors consider that the discrepancy is due mainly to the inappropriate assumption that the material is homogeneous and isotropic after plastic deformation. T. Udoguchi, Japan

Plates, Disks, Shells, Membranes

(See also Revs. 639, 640, 643, 657, 688, 692, 703, 726, 927)

678. Ozden, K., Bending of thin plates and variational laws in nonlinear elasticity (in German), *Ing.-Arch.* **24,** 3, 133–147, 1956.

Starting from a nonlinear law of elasticity indicated by Kauderer [title source **17**, p. 450, 1949], author derives the differential equation of the deflection of a laterally loaded plate for Cartesian as well as polar coordinates. The derivation is based on the usual assumptions of bending theory of thin plates. For a circular plate clamped along its edge and with a uniformly distributed load, the solution is obtained by substituting a power series for the deflection in the differential equation. Using a result of Argyris [*Aircr. Engng.* **26**, p. 347, 1954] on minimum energy for a nonlinear law of elasticity, author applies the method of Ritz and that of Galerkin. The numerical results obtained by these methods appear to be in good agreement with the former solution. Comparison of the results of the nonlinear theory with those of the usual linear theory shows that the differences between the values for the deflection as well as for the stresses are small (about one per cent).

Kauderer's law reads

$$\sigma_x = 3K\chi(\epsilon_0)\epsilon_x + 2G\gamma(\psi_0^2)(\epsilon_x - \epsilon_0), \text{ etc.},$$

$$J_{yz} = G\gamma(\psi_0^2)\psi_{yz}, \text{ etc.}$$

where $\epsilon_0 = 1/3(\epsilon_x + \epsilon_y + \epsilon_z)$

$$\psi_0^2 = 1/3\{(\epsilon_x - \epsilon_0)^2 + \text{etc.}\} + 2/3\{\psi_{yz}^2 + \text{etc.}\};$$

$$\chi/\epsilon_0 = 1 + \sum_{i=1} \chi_i \epsilon_0^{2};$$

$$\gamma(\psi_0^2) = 1 + \sum_{i=1} \gamma_{2i}\, \psi_0^{2i}$$

K, G, χ_i and γ_{2i} being constants of the material.
J. W. Cohen, Holland

679. Guerra, G., The deformation of thin walls loaded in their planes (in Italian), *Ricerca, Napoli* **5**, 4, 33–64, Oct./Dec. 1954.

The work deals with the problem of calculating the state of strain and the deformation of a rectangular disk liable to a continuous sine curve load perpendicular to the upper and lower edges.

Author solves the problem of the state of strain with the help of the following two cases of successive loading: (a) the sine curve continuous perpendicular load on the upper and lower edges, and, simultaneously, the continuous load (hyperbolic function) perpendicular to the two vertical edges, of the disk; and (b) the continuous load (hyperbolic function) perpendicular to the two vertical edges, opposite to the corresponding previous load.

The solution of the problem for the load (a) is achieved by the suitable determination of the intensive Airy function satisfying the circumscribed conditions of load; that is, producing exactly the given load (a) on the limits of the disk.

The solution of the problem for the load (b) is achieved by the determination of the Airy function with the help of the Ritz-Timoshenko method, with the simultaneous satisfaction of the circumscribed conditions. Tables Nos. 1–5 drawn up by the author give an important practical solution of the problem, since using the above cases of load, the maximum stresses on sections of the disk are directly calculated.

With the help of the known equations in the mathematical theory of elasticity, which solve the problem of the disks, author determines the vertical displacement of a point of the disk, taking into consideration the load boundary conditions and the case where the remote points of the lowest edge of the disk are vertically immovable.

Afterwards, he applied all the afore-mentioned to the calculation of the displacements of the points of the upper and lower edges for the above load and draws up a table of an immediate calculation of the maximum displacements of those edges. Finally, he gives a relevant example. C. Papaioannou, Greece

680. Botman, M., The effective width in the plastic range of flat plates under compression, Part III, *Nat. LuchtLab. Amsterdam Rap.* S. 465, 12 pp. + 3 tables + 69 figs., June 1955.

In order to determine the effect of the shape of the material stress-strain curve on the effective width (e.w.), author repeats experiments previously performed [AMR **7**, Rev. 2174] using 75 S-T and 2S-1/2H panels. The first material has a more pronounced and the second a more gradual transition between the elastic and the plastic parts of the curves than does 24S-T, the original material.

Experiments indicate that the 75S-T e.w. agrees fairly well with the e.w. determined theoretically. For the 2S-1/2H, however, there is considerable difference between the theoretical and experimental e.w., and the theoretical curves are not recommended for use. S. F. Borg, USA

681. McCalley, R. B., Jr., and Kelly, R. G., Tables of functions for short cylindrical shells, ASME Fall Meet., Denver, Colo., Sept. 10-12, 1956. Pap. 56-F-5, 24 pp.

Paper presents tables to facilitate solution of title problems. Basic theory is well known ("Theory of plates and shells," by S. Timoshenko). Four cases are considered: (1) One end of shell is fixed; other end is displaced a given distance, but slope is held as zero; (2) same as (1), but unfixed end is rotated through a given angle with deflection held zero; (3) both ends are fixed and applied internal pressure loading is uniform; (4) same as (3), but loading varies linearly with length. For each case, tables are given for deflection, bending moment, shear, etc., as a function of nondimensional shell length and a dimensionless shell parameter. Functions tabulated are elementary, as they are combinations of circular and hyperbolic functions. Y. L. Luke, USA

682. Niculescu, D. D., Precast shell elements of large roof structures. Part II (in Rumanian), *Indust. constr. Mater. constr.* **7**, 5, 265-276, May 1956.

Author applies simplified membrane theory to precast shell elements with double curvature. Results of the analysis are compared with loading tests of a section 21 ft wide, spanning 47 ft, as already described in part I [title source, no. 11, p. 574, 1955]. Fissures and cracks were observed and recorded under various concentrated loadings.

Reference is made to publications by L. Issenmann Pilarski, S. D. Rijik, M. Mihailescu, and M. Soare.

J. J. Polivka, USA

683. Tungl, E., Membrane stresses in an elliptic paraboloid (in German), *Öst. Ing.-Arch.* **10**, 2/3, 308-314, 1956.

By means of the stress function method of Pucher, author gives a solution for the membrane stresses in elliptic paraboloid shells. The solution contains eight functions in form of not-final sums, but their most important values are calculated and tabulated.

H. Neuber, Germany

684. Sonntag, G., Long cylindrical shell with axially unsymmetric edge load resulting from forces acting in longitudinal direction (in German), *Forsch. Geb. Ing.-Wes. (B)*, **22**, 4, 129-133. 1956.

For a thin cylindrical shell with small flexural rigidity, loaded at curved boundary only, D. Thoma discovered existence of a membrane state of stress, where all stress components but the axial normal stress vanish and where this normal stress is propagated without dispersion along the generators [A. Föppl, Anniversary Volume, 42-51, Berlin, 1924]. In order to investigate accuracy of Thoma's result, author uses bending theory of cylindrical shells in the approximate form given by K. Miesel [*Ing.-Arch.* **1**, 22-71, 1929] considering a cosine-shaped distribution of axial normal stress at boundary and introducing certain further simplifications. Dispersion of axial stress becomes notable for such loading cases where period of boundary distribution exceeds 60° of cylinder circumference.

F. K. G. Odqvist, Sweden

685. Berry, J. G., On thin hemispherical shells subjected to concentrated edge moments and forces, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955, 25-44.

The bending of a thin hemispherical shell with a nonsymmetrical rotational loading is discussed with the help of a stress function and the radial displacement both satisfying partial differential equation of the sixth order. Solutions are obtained in terms of Legendre functions of real and complex degree. Numerical results are given for the particular cases of two concentrated edge moments and a concentrated load at the apex. These compare favorably with those obtained from E. Reissner's shallow-shell theory, which gives good agreement with experimental results.

B. R. Seth, India

686. Tsuboi, Y., and Akino, K., Design and construction of reinforced concrete shell structure of non-uniform thickness supported on roller system, *Publ. int. Assn. Bridge struct. Engng.* **15**, 199-230, 1955.

Inspired by the shell structure built in Matsuyama in Japan, authors undertake to establish a theory for the analysis of shells with variable thickness. Paper is divided into three parts "Design," "Construction," and "Conclusions."

Part I contains a complete deduction of the basic equations and their approximate solution for the special case referred to above, assuming constant thickness. Further, a method of discussing the influence of variable thickness is given and numerical results from the practical design are presented. Part II is very short and contains a description and a few details of the structure.

Reviewer finds that references to a number of papers are lacking. The theoretical deductions shown are, to a great extent, to be found in papers by E. Reissner [*J. Math. Phys.* **25**, no. 1, 1946 and **25**, no. 4, 1947], Tölke [*Ing.-Arch.* **9**, 282-288, 1938], and some of the conclusions drawn may even be found in books on the subject [see S. Timoshenko, "Theory of plates and shells," McGraw-Hill, 1940]. The text is not written in good English and contains sentences which may be misunderstood and also a number of misprints. A reader may, for instance, be inclined to doubt the mathematical ability of the authors by reading the following statement on the basic equation: "The equation which is derived for the above-mentioned purpose is, of course, a partial differential equation of higher order because one of the variables is φ (meridian direction) and the other is θ (latitude direction)."

Reviewer is indebted to his colleague Dr. O. Jenssen for giving the references. L. N. Persen, Norway

Buckling Problems

(See also Rev. 695)

687. Larsson, L. H., Inelastic column buckling, *J. aero. Sci.* **23**, 9, 867-873, Sept. 1956.

Using analytical stress-strain law, author develops theory of centrally compressed, initially curved column. Approximate solution obtained on assumption that deflection curve is half-sine wave is applied to idealized H-section column. Results show that tangent modulus theory yields better approximation for maximum load than reduced modulus theory.

G. G. Meyerhof, Canada

688. Thielemann, W., and Dreyer, H. J., Contribution to the question of buckling of thin-walled axially compressed circular cylinder (in German), *Dtsch. Versuchsanstalt Luftfahrt E. V. Rep.* 17, 29 pp., June 1956.

It is known that buckling stresses of compressed circular cylindrical shells obtained on the basis of the classical theory are in complete disagreement with stresses obtained by experiments. Von Kármán and Tsien attempted to explain the discrepancies by the large-deflection theory. Using the same theory, Donnell improved on their contribution by considering the influence of possible initial imperfections of the shell surface and the yield point of the material on the stability of thin cylinders. Further extending Donnell's work, authors attempt to explain theoretically not

only the discrepancies but also the wide scattering of the experimental values of buckling stresses by assuming initial imperfections of various magnitudes. Using Donnell's method, authors plot stresses as functions of so-called "cylinder characteristics" $\zeta = \sigma_F r/Et$ and ratios a_0/t, where σ_F denotes the yield stress, r radius of the cylinder, E modulus of elasticity, t thickness of shell, a_0 amplitude of the initial imperfection. The existing experimental results of seamless tubing agree very well with the theoretical stresses, and it is thus possible to predict the failing buckling stresses from the comparison of the curves. This method does not give satisfactory results for welded or riveted tubes because of the insufficiency of available data, and further test data will be necessary to enable one to use authors' method for welded and riveted cylinders. M. Maletz, USA

689. Laszlo, N., Considerations in design of columns in reinforced concrete supporting crane girders and precast-concrete roof trusses (in Rumanian), *Indust. constr. Mater. constr.* **6**, 1, 44-49, Jan. 1955.

Three design schemes of precast-concrete columns in multiple-bay buildings are structurally investigated and their costs compared: (1) columns restrained in the footings and free at the tops, permitting elastic swaying; (2) columns restrained in the footings and hinged at the tops, whereby the swaying is eliminated by lateral rigidity of the roof structure; (3) columns rigidly restrained at both ends. The results pertaining to economy are based on structural analysis and design of a 4-bay industrial building with 60-ft spans (bowstring trusses), 30-ft columns carrying also crane girders of the same span. Also, rigid connections between precast members are described and illustrated. It is concluded that rigid connections between columns and trusses reduce the bending moments in the upper slender part of the columns 5-10%, and in the lower heavier part (under the crane brackets) 25-30%. The economy consists primarily in considerable saving in reinforcement. Reference is made to the book on reinforced concrete by C. V. Sahnavschi. J. J. Polivka, USA

690. Campus, F., and Massonnet, C., Investigation of the buckling of A37 steel column with double T profile obliquely loaded (in French), *Bull. Centre Étud. Constr. génie civ. Hyd. Fluviale* **7**, 119-338, 1955.

Paper covers extensive experimental studies of I and wide flange column sections. Methods are presented that permit precise analysis of the behavior of columns loaded eccentrically and obliquely. The real properties of the metal and residual stresses are included in the studies. C. F. Peck, Jr., USA

691. Hoff, N. J., Thermal buckling of supersonic wing panels, *J. aero. Sci.* **23**, 11, 1019-1028, 1050, Nov. 1956.

The subject of paper is important for modern high-speed aircraft. Under simplifying assumptions, —plane panels, constant heat flow into structure, radiation and convection disregarded, cover plate and web extending to infinity from a juncture point—temperature distribution is determined. Validity of use of known temperature distribution in semi-infinite rods is evaluated in terms of time from start of heating.

Thermal stresses in cover plate are obtained by the aid of a simplifying assumption using hypothetically cutting of the cover plate into narrow strips. These are loaded by forces corresponding to thermal expansion of each strip. Thermal stresses are represented by Fourier series. To this end, Laplace transformation is applied.

Equations for buckling are obtained by inserting the Fourier series for stresses and a Fourier series for the plate deflection. The determinant equation for buckling is triangularized, and by means of continued functions approximate values for the buckling stress are obtained. Further, the buckled shape is discussed. A numerical example is given to illustrate application.

B. Langefors, Sweden

692. Csellar, O., Buckling of thin plates in case of initial curvature (in Hungarian), *Mélyépitéstudományi Szemle* **6**, 5, 213-223, May 1956.

693. Zyczkowski, M., Application of the enclosed "a priori" assumption of an exact equation on some problems of elastic, plastic stability (in German), *Bull. Acad. Polonaise Sci.* **4**, 1, 37-43, 1956.

694. Hult, J. A. H., Creep buckling of columns—bibliography (in Swedish), Roy. Inst. Technol., Stockholm, Div. Strength of Materials, Publ. no. 109, 15 pp., 1955.

Papers on theoretical and experimental study of creep buckling of columns reviewed through 1954. Nonlinear theories by N. J. Hoff, J. Kempner, and F. K. G. Odqvist appear to fit experimental evidence. From author's summary

Joints and Joining Methods

(See Revs. 716, 722, 731)

Structures

(See also Revs. 646, 647, 665, 667, 670, 671, 672, 676, 683, 689, 691, 724, 824, 870, 914, 927, 935, 942, 947, 948)

Book—695. Gerard, G., Minimum weight analysis of compression structures, New York, New York University Press, 1956, xxi + 194 pp. $6.

The accelerated development of the art of optimum structural design of aircrafts can be seen by author's bibliography of 49 articles and books, most of which were published since the end of the second world war. Author does a very thorough job of putting the scattered information together and of making a unified treatment of the minimum weight analysis of aircraft structures subject to compression buckling. The book is divided into 11 chapters.

In chap. 1, author explains the principle of minimum weight design by considering individual compression element subject to buckling and illustrates how to combine the given intensity of loading and the prescribed leading dimensions of the structure for a "structural index" to be used as the governing parameter for optimum design.

Chapter 2 is devoted to an introductory remark on the behavior of composite structures and a general discussion on the optimum design parameters in conjunction with the bending of wing, tail, and fuselage elements which consist of compression covers and supporting structures.

The following five chapters analyze the minimum weight configuration of the following structural arrangements: (a) Stringer panel-rib construction; (b) transversely stiffened plates; (c) post construction; (d) multicell construction; (e) post-stringer construction; (f) sandwich-plate construction; (g) sandwich-box construction; (h) unstiffened cylindrical shells; (i) stringer panel-frame shell; (j) sandwich shell.

A comparison of the various types of construction is given in chap. 8, using 75S-T aluminum alloy as the typical material. Design charts are provided, from which the ranges of efficient structural application of each form of construction can be established.

In chap. 9 author discusses the possible deviations of the previous conclusions from practical considerations. In chap. 10 author points out the relative material efficiencies at normal and elevated temperature.

The last chapter is devoted to the discussion of minimum weight design of structures for which the leading dimensions may be regarded as open dimensions.

The book does not provide sufficient information for readers who seek complete structural design data. For example, in a section on the comparison of stiffened panels of various stringer types, author does not include the actual dimensions of the stringers but refers to several *NACA Technical Notes* for further information. Reviewer also suggests improvements in the presentation of the design charts. Many of these, in particular those in log scale, would be much more convenient to designers if finer divisions were included. Some of the charts which are too crowded perhaps should be presented in larger scales.

Reviewer recommends this book very highly for aeronautical engineers. T. H. H. Pian, USA

696. Kappus, R., Contribution to the rigidity matrix calculation (in French), *Rech. aéro.* no. 52, 43–49, July/Aug. 1956.

The elastic behavior of a delta wing can often be considered as due to the interaction of beams which criss-cross and a torsion box. The junction of these different parts can be made to enter into the calculation of certain matrixes of rigidity. In order to avoid the introduction of intermediate points, one considers the development of the quantities $1/EI$ and $1/AS$ as linear in the different parts. The principal formulas developed are hardly more complicated than those based on mean values, and they give more accurate results.

From author's summary by E. J. Scott, USA

697. Boley, B. A., On thin-ring analysis, *J. aero. Sci.* **23,** 8, 802–804 (Readers' Forum), Aug. 1956.

A formula giving explicitly the bending moment at any point of a closed ring of arbitrary shape under arbitrary loadings in the plane of the ring is derived by the classical method of least work. The result is not new. [See, for instance, Parcel and Moorman, "Analysis of statically indeterminate structures", p. 184, Eqs. 10 and 11]. M. L. Pei, USA

698. Goodey, W. J., The stress analysis of the circular conical fuselage with flexible frames, *J. roy. aero. Soc.* **59,** 536, 527–550, Aug. 1955.

This paper is concerned with the problem of the skin-and-stringer-covered conical fuselage of circular cross section, having flexible frames and being subjected to an arbitrary distribution of loads applied in the planes of these frames or on the end cross sections. The skin thickness and stringer cross section may vary from bay to bay but are assumed to be constant in a bay, i.e., between any two consecutive frames. The stringers are assumed to be uniformly spaced round the circumference. The frames are assumed to be of uniform cross section (circumferentially) but their stiffnesses are arbitrary, as is also their spacing along the fuselage.

This paper is a sequel to one previously published ["The stresses in a circular fuselage," title source, Nov. 1946], but the method of analysis is now by minimum strain energy instead of by deflections. Owing to the generality of the investigation it is impossible to present the solution—in terms of the known loads and stiffnesses—in any explicit form, and attention has therefore been concentrated on the technique of numerical computation. A scheme of tabulation has been evolved, and its use is illustrated by a fully worked numerical example of a moderately complex type.

From author's summary by Y.-Y. Yu, USA

699. Szabo, J., Calculation of grills with the help of matrix method (in Hungarian), *Mélyépitéstudományi Szemle* **6,** 5, 210–212, May 1956.

700. Bateman, E. H., The development of the elastic theory of continuous frames, *Struct. Engr.* **33,** 3, 73–83, Mar. 1955.

The historical development of methods of analysis, for use in the design of continuous frames, is traced from the introduction of the theorem of three moments, almost a hundred years ago, to the contemporary application of electronic digital computers. The types of frame under consideration range from the highly redundant skeleton of a city building to the highly deformable structure of a large span single-storey building or hangar. The analysis is restricted by the conventions of practical structural engineering design, namely, that axial deformations of frame members may be discounted, and that columns are not so slender as to raise problems of elastic instability. The principal methods—moment-area, slope-deflection, strain-energy, moment-distribution, relaxation, etc.—are briefly summarized, and a case is presented for the need of more than one method to meet different design requirements. From author's summary

701. Wood, R. H., A preliminary study of composite action in framed buildings, *Publ. int. Assn. Bridge struct. Engng.* **15,** 247–265, 1955.

The stiffening effects of walls and floors in framed structures is reviewed in the light of recent developments in the theory of composite structures. The main problem appears to be the determination of the actual load distribution on the beams of a supporting frame, which distribution can vary considerably. In this connection there is an analogy between the stiffening effects of walls and floors. The combined behavior of floors supported on beams is examined at working (elastic) conditions and at impending (plastic) collapse. It is shown that the loads on the beams at collapse may be decided by the placing of the reinforcement. In an effort to minimize the reinforcement by limit-analysis methods it is shown that, with reinforced-concrete floors, an elastic design forms a surprisingly good starting point for the most economical collapse design. From author's summary

702. Lyle, E. S. E., Analysis of gable frames by the column analogy method, *Concr. constr. Engng.* **51,** 6, 389–394, June 1956.

703. Olszak, W., and Sawczuk, A., Experimental verification of the limit analysis of plates, Part 1, *Bull. Acad. Polonaise Sci.* 3, 4, 195–200, 1955.

704. Miladinovic, Z., Preparation of concrete test samples (in Serbian), *Naše Gradevinarstvo, Beograd* **10,** 7, 985–987, July 1956.

Typical sizes and shapes of concrete samples for testing are discussed and some of their inconveniences emphasized, especially the effect of their preparation on compactness. Author proposes a new method of compacting the samples for uniform comparison. J. J. Polivka, USA

705. Arredi, F., Experimental research of impermeability of concrete in large hydraulic structures (in Italian), Science Sec., Dept. hydr. Struct., Univ. Rome, Paper 30, 15 pp. + 3 illus., 1954; *Acque* no. 7-8, July-Aug. 1954.

Test specimens were not cast in moulds but obtained as drilling cores from mass concrete in order to eliminate the disturbance of aggregates near the mould walls and concentration of mortar and finest particles. Cylindrical specimens 0.14 in. high, having outside diam. 11½ in. and inside diam. 2 in., were prepared by special drilling equipment of the Laboratory. Research was done with specimens of variable characteristics as to grading, quality of cement, water-cement ratio, and time of hardening. Special equipment was designed for measuring the permeability, consisting of a rugged iron bell bolted to a horizontal plate and made watertight by a gasket. The test specimen is placed at the center of this plate and made watertight by rubber disks with coating and pressed on the top by another smaller plate. The bell is supplied with water by a small piston pump, the pressure of which is controlled by a relief valve and measured by a gage at the top of the bell. The water is let out through a hole in the supporting plate.

For mixing concrete, Swedish vibrators were used, operating at 12,000 shocks per minute. Specimens were drilled and cut 40 days after casting and kept under damp sand.

Permeability tests were conducted as follows: during 1st day the pressure in the test bell was kept for 1 hr at 5 atm, increased to 10 and 15 atm after one hour interval. After this soaking, the pressure was kept constant at 15 atm for 8 hrs, and the quantity of water percolated during the second, third, and the last five hours was measured, and the permeability coefficient was determined by generally known formulas. The results of tests are tabulated and presented in graphs. Conclusions: (1) Tests on 45-day old concrete are usually sufficient, although in some cases a slight decrease in permeability is possible in older concrete. (2) Two-day test is sufficient. (3) Greater number of specimens for each individual test is recommended. (4) In thin structures, absolute impermeability is not attainable. (5) Pozzolan cement is better. (6) In general, fine particles do not increase the impermeability if the vibrated mortar is sufficiently fluid and diffuses into the aggregate framework. (7) If the mix is very poor in fine particles, the mortar concentrates rather in the lower layers. (8) Aggregate framework must be completely submerged by the mortar without inclusions of pure mortar layers between successive casts. (9) Good impermeability was attained with the widest range of water-cement ratio (up to about 0.65).

J. J. Polivka, USA

706. Arredi, F., Pandolfi, C., and Paimieri, A., Experimental research on the ratio between the bending and tensile strength of concrete (in Italian), Science Sec., Dept. hydr. Struct., Univ. Rome, Paper 28, 8 pp. + 5 illus., 1954.

Using the same kind and content of cement and with water contents corresponding to the same workability, specimens of different mixes with aggregates of different properties were tested. For bending strength, prismatic specimens $6\frac{1}{2} \times 6\frac{1}{4} \times 14$ in. were used, placed vertically, fixed at both ends, and subjected to bending by a horizontal lever under load. The measuring system can also exert progressively increasing vertical force. This device produces constant bending moments without shear (slight compressive stress—about 3% of bending stress—cannot be eliminated). For tensile strength, cylindrical specimens 6×12 in. were used.

Results: (1) The ratio practically does not change with the age of concrete (approx. 2). (2) Ratio is not affected by water-cement ratio, nor by kind of cement. (3) Ratio does not vary greatly with the kind of aggregates and the size. (4) 62 average values vary between 1.5 and 2.4, the over-all average value being 1.97; however, 53 (approximately 87%) of them show variation between 1.7 and 2.2.

Theory of probability is applied to determine more accurately the ratio on the basis of a few preliminary tests. The study substantiates the hypothesis that the variability of the ratio observed in the experiments is rather accidental, and, therefore, a mean constant value of any type of concrete can be assumed about 1.98.

J. J. Polivka, USA

707. Arredi, F., Pandolfi, C., and Paimieri, A., Determination of the hardening rapidity of concrete, Science Sec., Dept. hydr. Struct., Univ. Rome, Paper 27, 5 pp. + 3 illus., 1954.

Special apparatus of G. Bordoni, National Research Council (Institute of Ultraacoustics) was used which is based on the principle of applying electrostatic vibrations to the specimen, the frequency of which can be regulated. The frequency modulation is converted through circuits into amplitude modulation, and the fundamental resonance can be found. The apparatus is used for determination of the modulus of elasticity. Numerous concrete specimens (16×32-cm cylinders) were tested electrodynamically and by axial compression. Advantage of the electrodynamic method is the possibility of testing very fresh concrete (1–2 days old) without damage and of measuring the hardening behavior in relation to various physical conditions. Specimens were of crushed calcereous aggregates, in proportions to grading curve (incl. cement). Specimens were prepared in metal moulds, tamped with a high-frequency immersion vibrator. After 24 hrs, moulds were removed and specimens placed: (a) in damp sand, (b) immersed in water at 15C surrounding temperature, (c) same at 50C, and (d) in air of 50C temperature and 30% relative humidity.

Results: (a) modulus of elasticity (measured electrodynamically) normal, increasing from approximately 4 mil. psi (after 3 days) to 6 mil. psi (at 28 days), and to $6\frac{1}{2}$ mil. after 180 days with 5,500 psi ultimate crushing strength; (b) E similar to and strength (a) values; (c) more rapid hardening, E = 5 mil. psi at 3 days, much higher, however, approaching the values of (a) and (b) specimens at 28 and 180 days, with the ultimate compressive strength 6,100 psi; (d) at 3 days E only 95% of the value of specimen (a), still relatively decreasing with the time, reaching 3.9 mil. psi at 180 days, with the compressive strength of 2,500 psi at this period.

J. J. Polivka, USA

708. Rodojkovic, M., Is it justified to give preference to concrete over steel in structural design? (in Serbian), *Naše Gradevinarstvo, Beograd* **10,** 5, 669–671, May 1956.

Author discusses title question, considering present conditions in Yugoslavia. Today there is sufficient production of steel in Yugoslavia so that the most economical material can be chosen in any structural design. Serious disadvantage of steel structure is the relatively smaller safety factor, especially in cases where live load (e.g., snow) can exceed the assumed intensity. Each case should be thoroughly investigated under all conditions.

J. J. Polivka, USA

709. Sorifca, L., and Trustul, L., Experience in design and construction in various fields of prestressed concrete and resulting recommendations (in Rumanian), *Indust. constr. Mater. constr.* **7,** 4, 222–234, Apr. 1956.

A large number of I-shaped prestressed girders are described (maximum length 60 ft) and their design and precasting discussed. Posttensioned cables were used with Korovkin's system of anchorage. Comparative costs for various spans are analyzed and tabulated. Special instruments for checking prestressing were used.

J. J. Polivka, USA

710. Cowan, H. J., and Armstrong, S., Experiments on the strength of reinforced and prestressed concrete beams and of concrete-encased steel joists in combined bending and torsion, *Mag. Concr. Res.* **6,** 19, 3–20, Mar. 1955.

A series of reinforced and prestressed-concrete beams and concrete-encased steel joists were tested in combined bending and torsion, with ratios of bending moment to twisting moment varying from pure bending to pure torsion. In all, 33 full-size beams were tested. Measurements of deflections and strains due to bending and to torsion were made at selected points. The agreement between theory and experiment was generally good.

The torsional strength of concrete can be augmented by suitable shear reinforcement. The resistance of the reinforced-concrete beams to torsion, however, still depends on the tensile strength of the concrete; it is not therefore possible to gain an increase in strength comparable with that resulting from the addition of tension reinforcement to a plain concrete beam subject to bending. On the other hand, the insertion of even a small quantity of shear reinforcement turns the abrupt torsion failure of plain concrete into a gradual failure accompanied by considerable cracking and deformation.

The torsional strength of a concrete-encased steel beam is approximately the same as that of a similar plain concrete beam. The "I" shape is fundamentally a weak one in torsion and the concrete encasement therefore results in a considerable increase

in the torsional strength of the steel joist, provided that the joist is surrounded with a nominal amount of stirrup reinforcement or expanded metal to insure that the steel and concrete act together.

Very large increases in torsional strength can be obtained by prestressing, since the initial prestress in compression must be overcome before the concrete can be stressed in tension. The prestressing force, however, increases the rate at which cracks propagate during failure, which therefore tends to assume a violent character.

Two distinct types of failure can be distinguished in beams subject to combined bending and torsion. A primary torsion failure occurs with a cleavage fracture normal to the direction of the principal tension. It is governed by the criterion of a constant maximum tensile stress. In bending, tension failure is prevented by the steel, and a primary bending failure therefore results in the crushing of the concrete on the compression face.

In reinforced-concrete and concrete-encased steel beams the addition of bending *increases* the resistance to torsion.

Paper concludes with detailed recommendations for the design of reinforced and prestressed-concrete beams and concrete-encased rolled steel joists in torsion, and in combined bending and torsion. From authors' summary

711. Billington, D. P., Building frames in prestressed concrete, *J. Amer. Concr. Inst.* **27,** 10, 1065–1081, June 1956.

Three important variables in the design of economical prestressed-concrete building frames are: (1) tendon profile, (2) girder cross section, and (3) girder profile. The action of each variable on the effectiveness of the frame in carrying its load is considered. Types of frames considered are those in which (1) frame is posttensioned, (2) girder only is prestressed, and (3) prestressing force is constant throughout girder length. Criteria are offered for selecting an efficient framing system for detailed frame analysis. From author's summary

712. Dimitrijevic, D., An original method of draining non-walled traffic tunnels (using drain elements in reinforced concrete), *Naše Gradevinarstvo* **10,** 1, 38–40, 12 illus., Jan. 1956.

Paper describes the road tunnel "La Graou" in French Alps, built through solid rock. To prevent water dripping, precast concrete arch shells were installed, spanning 24 ft (7.10 m), in units 3 ft 3 in. (1.00 m) wide, resting on continuous concrete beams at a height of 11 ft 6 in. (3.57 m) above the road, with drainage holes inside. The shell units are 2 in. (5 cm) thick and stiffened on each side with arch ribs, of 2⅜ in. × 3 in. section. Concrete drainage ducts 1 ft 9 in. (44 cm) wide are also provided under sidewalks. Seven photos show the construction method of installing the shell units. J. J. Polivka, USA

713. Hangan, M., Characteristic problems in design and erection of prefabricated structures in reinforced concrete (in Rumanian), *Indust. constr. Mater. const.* **6,** 1, 19–27, Jan. 1955.

Various types of roof structures precast in reinforced concrete are described and compared with similar steel structures, with emphasis on differences in design, assembly, and erection, and possible alternatives, considering the economy. Various combinations of hinged girders and trusses are discussed and connections of members described, emphasizing the advantages of welding reinforcing bars. Types of roof girders are presented which permit good daylight illumination. Modular design is recommended, typical dimension being 3 m (approximately 10 ft). J. J. Polivka, USA

714. Kollbrunner, C. F., and Streuli, L., Sealing in hydraulic steel constructions (in German), Mitt. Forschung und Konstruction im Stahlbau no. 18, 34 pp., July 1956.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 652, 653, 668, 677, 680, 693, 694, 727, 728, 735, 739, 749, 750, 751, 768, 914)

715. Bland, D. R., Elastoplastic thick-walled tubes of work-hardening material subject to internal and external pressures and to temperature gradients, *J. Mech. Phys. Solids* **4,** 4, 209–229, Aug. 1956.

Tresca's yield and plastic potential functions are used. Outer surface and bore are maintained at different temperatures. Expressions for stresses, strains, and displacements up to the moment when the tube becomes fully plastic are obtained. In general, a numerical integration is necessary but the solutions can be given explicitly for linear hardening. Examples include partly plastic closed-ended, nonhardening tubes with rising, falling, and zero temperature gradients from bore to outside. It is remarked that the stresses are roughly comparable, but there is considerable variation in displacements. Elastic unloading is examined. Comparison between nonhardening and hardening fully plastic tubes with zero temperature gradient and outer-to-bore radius four is made. It is found that both tubes are partly plastic on unloading. J. F. W. Bishop, Scotland

716. Bodine, E. G., Carlson, R. L., and Manning, G. K., Interaction of bearing and tensile loads on creep properties of joints, *NACA TN* 3758, 23 pp., Oct. 1956.

The objective of this investigation was to study the interaction of bearing and tensile loads on the creep behavior of joints. To achieve this objective, a specimen was designed which possessed some of the general features of pin and rivet joint connections. An apparatus was constructed to apply both bearing and tensile loads to the joint model.

Measurement of deformation was accomplished by the use of a photogrid printed on the joint model. Analysis of the deformation patterns indicates that the form of the strain-history curves at some points in the simulated joint is similar to that of the strain-history curves for uniaxial tensile creep tests. Further, there appears to exist a steady-state period during which certain creep strain rates remain constant. This may imply that the stress distribution during that period is also constant over part of the specimen.

For the tested specimens, hole elongation due to combined bearing and tensile loading was composed of an elongation due to the total tension plus an elongation due to bearing. When the bearing load was not excessive, the elongation due to bearing appeared to be transient, and additional hole elongation continued at a rate that was approximately equal to that for a tensile load of the same total magnitude.

The fracture appearance of specimens subjected to tension and of specimens subjected to tension and bearing was similar. The extent of certain fracture zones differed for the two cases, however.

The results of this exploratory study indicate that several features of the deformation behavior may be amenable to a simplified analysis. Before final conclusions can be made, however, more detailed measurements should be made, and additional tests should be conducted. From authors' summary

717. Griffith, J. E., and Marin, J., Creep relaxation for combined stresses, *J. Mech. Phys. Solids* **4,** 4, 283–292, Aug. 1956.

A theory of stress relaxation and creep for combined stresses is developed. It is based on the creep law

$$\epsilon = \sigma/E + k_1\sigma^n + k_2\sigma^n[1 - \exp(-qt)] + k_3 t\sigma^n,$$

which is postulated for each principal strain ϵ; σ is stress, t time, the other parameters are constants. The four terms of the law give, respectively, the elastic, plastic, transient, and steady-

state components of creep. The general expression for the total principal strains in terms of the principal stresses is given. The equations can not be solved directly for the stresses since they appear in mixed terms and are raised to various values of the exponents. Thus a Taylor series expansion method is used. Several particular cases are solved and the results are compared with data from combined stress relaxation tests. Approximate agreement is found. B. Gross, Brazil

718. **Bland, D. R., and Lee, E. H., On the determination of a viscoelastic model for stress analysis of plastics,** *J. appl. Mech.* **23,** 3, 416–420, Sept. 1956.

The simplest spring-and-dashpot model of a viscoelastic body which exhibits each of the phenomena of instantaneous elasticity, viscous flow, and delayed elasticity is the four-element Voigt model. Authors derive graphical test to determine whether Voigt model can adequately represent experimental stress-strain data over entire or limited range. Graphical method is presented for determining parameters of model; techniques are illustrated by worked-out example. Same procedure is developed for four-element Maxwell model, which authors claim to be less useful.
I. M. Krieger, USA

719. **Narasimhan, M. N. L., On the steady laminar flow of certain non-Newtonian liquids through an elastic tube,** *Proc. Indian Acad. Sci.* (A) **43,** 4, 237–246, Apr. 1956.

Author makes a mathematical study using the Reiner-Rivlin stress-strain-velocity relations. The effect of inertial forces and viscosity diminishes the tube radius with distance along the tube axis. Work shows that the effect of cross viscosity compensates for the viscosity and inertial forces in flow. Poisson's ratio effect on tube shape is not examined.
P. Whitton, England

720. **Tyabin, N. V., Radial flow of viscous-plastic dispersion systems in a flat capillary** (in Russian), *Dokladi Akad. Nauk SSSR* (*N.S.*) **96,** 1, 29–32, May 1954.

Failure, Mechanics of Solid State

(See also Revs. 661, 745)

721. **Kheiralla, A. A., Theory of fatigue fracture,** *J. appl. Mech.* **23,** 3, 473–474 (Brief Notes), Sept. 1956.

Note suggests a modification of theory of Yokobori ["Theory of fatigue fracture of metals," AMR **9,** Rev. 1822]. This theory is based on reaction kinetic argument in which the frequency of crack-nucleation is proportional to the frequency of atomic vibration (kT/h). Author substitutes instead the loading frequency, which leads to a better agreement with experimental results of the usual low-frequency fatigue tests. F. Forscher, USA

722. **Schijve, J., The fatigue strength of riveted joints and lugs,** *NACA TM* 1395, 54 pp., Aug. 1956.

723. **Kheiralla, A. A., A new theory of fatigue,** *Naturwissenschaften* **43,** 14, 321–322, July 1956.

Author assumes that, for each cycle at nominal stress σ, an incremental stress vector in the principal stress space of magnitude σ and random direction is added to the state of stress at the point of the material where failure will occur. The criterion for failure is the intersection of the sum of the incremental stress vectors with a failure surface, such as a right circular cylinder. Reviewer fails to see connection between this model and the usually observed formation of a crack on a slip surface within a grain, followed by growth to failure. F. A. McClintock, USA

724. **Payne, A. O., A note on the fatigue of wings,** *J. aero. Sci.* **23,** 8, p. 797 (Readers' Forum), Aug. 1956.

A series of fatigue tests has recently been completed at the Aeronautical Research Laboratories on 90 P51-D Mustang mainplanes. The structure of this mainplane is regarded as being representative of a large class of riveted 24ST aluminum-alloy wings, and the project has provided comprehensive information on the fatigue characteristics of such a structure.

Tests showed that the effect on the fatigue characteristics of the varying service life experienced prior to test by some of the wings used was negligible. Consequently, all the test results have been pooled, and, further, since both port and starboard halves are practically identical, a half wing was taken as the unit specimen.
From author's summary

725. **Valluri, S. R., Developments in fatigue crack detecting systems,** Cal. Inst. Technol., So. Cal. Coop. Wind Tunnel Rep. P-5, 14 pp. + 9 tables + 4 figs., July 1955.

In 1948 one of the blades of the Southern California Cooperative Wind Tunnel propellers broke due to fatigue failure and, due to the unbalance developed thereby, resulted in major damage to the tunnel.

While seeking methods of preventing a similar catastrophe, a research program was initiated in order to develop a reliable fatigue-crack-detecting system of the wire type. The basic principle is to lace the region of stress concentration, which in this case is fairly well defined, with thin insulated wires and to connect the ends to a relay circuit so that when a crack develops, it will produce an open circuit in the wire and this in turn will actuate a relay to prevent further application of stress. It is evident that, when all the elements involved are working well, an open circuit in the wire will mean a crack; therefore, based on this principle, suitable precautions may be taken.

The basic work in this method was conducted by Foster at Lockheed at the suggestion of Shanley. This method was also used by McGuigan in the full-scale investigation of the fatigue characteristics of aircraft which appeared in *NACA TN* 3190. Since it was felt that Foster's work was not sufficiently exhaustive, it was considered desirable to go into the problem in a more detailed manner. This report is consequently considered a further development in the same field in order to check the reliability and the variables involved in this problem.
From author's summary

726. **Meyer, A. J., Jr., Kaufman, A., and Caywood, W. C., The design of brittle-material blade roots based on theory and rupture tests of plastic models,** *NACA TN* 3773, 46 pp., Sept. 1956.

Paper deals with problem of turbine and compressor blade-root design for brittle materials such as ceramics, whose use is necessitated by high temperatures. Design charts based on Neuber's equations for notch stresses are presented, and theoretical strengths compared with results of experiments on brittle plastic models. Eighteen different root designs are compared.

Besides providing guidance in root design, paper affords a check on the accuracy of the Neuber equations in predicting rupture strength and indicates, as have other reports, the value and practicability of brittle model tests. Authors' statement that minute scratches, etc., have pronounced effect on rupture strength of brittle materials and thus account in part for deviation in test results is at variance with reviewer's observations.
R. J. Roark, USA

727. **Faupel, J. H., Yield and bursting characteristics of heavy-wall cylinders,** *Trans. ASME* **78,** 5, 1031–1064, July 1956.

Although author cracked up nearly one hundred closed-end, heavy-walled, hollow cylinders made of various kinds of steels and aluminum bronze, tested under internal pressure at room and a few slightly elevated temperatures (below the creep range), the re-

port offers, apart from the curves representing the observed pressures in their dependence on the tangential (hoop) strain at the outer surface of the cylinders, little insight into the laws governing the stresses at the instant of fracture after the tube material was deformed plastically. Since the tensile elongation at fracture in tensile bar tests varied between 20 to 80 % in the more ductile metals, quite appreciable permanent strains must have occurred in the hollow tubes before the fracture, changing, for example, the true ratio of the outside to the inside radius $R = C/\alpha$ in the hollow cylinder while the test was in progress. In spite of this fact, which would have required distinguishing between the conventional and the natural permanent strains and considering the strain-hardening of the tube material, all that author does is to quote the well-known formula expressing the internal pressure $p = [2\sigma_y/(3)^{1/2}]$ $ln\ R$, valid for an ideally plastic substance (σ_y yield stress in tension) and to use it at the ultimate stress with a changed value of σ_y, writing for it σ_u = the ultimate tensile stress (nonexistent even in a simple tensile test overlooking that the true stress at the ultimate strength is $\sigma_u(1 + \epsilon_u)$, ϵ_u strain at ultimate strength). Author then postulates that the bursting presure p_b will be a function of the former and of the latter expression of p by adding both values multiplied by the factors σ_y/σ_u and $\left(1 - \frac{\sigma y}{\sigma u}\right)$, respectively. This formula, obscurely averaging two arbitrarily selected pressures, can not be rated even as an empirical formula.

In view of present-day knowledge of the plastic behavior and of the conditions of fracture under combined stress in ductile metals in the strain-hardening range of their deformations, (to which, incidentally, not a single reference could be seen in the text), formulas of this type are damaging the humble art of designing pressure containers in the minds of mechanically, just-a-little-inspired engineers. A. Nadai, USA

728. Peltier, R., Experimental and theoretical study of the rupture of concrete (in French), *Tech. mod. Constr.* **10**, 12, 518–522, Dec. 1955.

On the basis of compression tests up to rupture on concrete cubes and prisms (provided, however, that the influence of friction is prevented from occurring on the surfaces of contact between the experimental sample and the press) author comes to the following conclusions: (a) The compression strength of cubes tested as stated above has proved greater, by about 11%, compared with the results obtained by the classic method of testing. In a series there is less dispersion of results; cracking occurs parallel to the direction of the greatest normal stress; (b) after testing kept under constant compression the resulting *static compression strength* of concrete amounts to ⅔ of the strength of the prism or ½ of that of the concrete cube. D. Krsmanovic, Yugoslavia

729. Gibb, C., Report on investigation into the failure of two 100-MW. turbo-generators, *Proc. Instn. mech. Engrs.* **169**, 29, 511-538, 1955.

Paper describes the investigations made following the failure of two generators each of 100 mw capacity installed in the Richard L. Hearn Generating Station at Toronto of The Hydro-Electric Power Commission of Ontario. Author details some general considerations affecting the design of alternator rotors, the selection of materials used, past troubles which had to be avoided, reasons for certain features incorporated in the original design and modified as the result of the failures, and safeguards introduced into current practice to avoid the possibility of a repetition of the failures. From author's summary

730. Hundy, B. B., Determination of residual stresses in lightly rolled thin strip, *J. Iron Steel Inst. Lond.* **179**, part I, 23–29, Jan. 1955.

Unidirectional residual stresses which vary through the thickness of a thin sheet-steel specimen may be determined by etching away one face of the specimen and measuring the corresponding change in curvature. The reproducibility of the results is good and the analysis is not very tedious. If a number of specimens are tested at the same time, the thickness-curvature relation for each specimen can be obtained in about 8 hr, and the residual-stress distribution can be calculated from these results in about 2–3 hr. Although the method described has a particular application to mild steel, it can be applied with equally good results to other metals, such as copper.

It was found that the magnitude and distribution of the residual stresses in rolled mild-steel strip changed as the rolling reduction was varied (up to 6% reduction). Generally the residual stresses increased in magnitude as the reduction was increased. In rolled copper strip, on the other hand, there was a tendency for the residual stresses to decrease slightly as the reduction was raised. From author's summary

731. Fosberry, R. A. C., An investigation of stresses in public service vehicle type wheels, *Instn. mech. Engrs. Auto. Div.* Part III, 91–103, 1952–1953.

The causes of failure in wheel rims have been only recently investigated and this paper is a contribution dealing with public service vehicle type wheels.

Various types and sizes of wheel are considered, statically and dynamically, with differing tire sizes. The results obtained with wire resistance strain gages are claimed to be more reliable than those achieved by the deflection method. Stresses in the critical parts of a wheel are produced by assimilating the forces which would be experienced in service, including bumps, corners, and braking.

The influence on wheels of acceleration on corners and deceleration due to braking is examined and results shown. Stress analysis of a wheel is only part of the design problem, since residual stresses induced during manufacture, the properties of the material, and the order of severity of service conditions have also to be taken into account.

The investigation concludes with a comparison of a welded wheel and a riveted wheel, but the latter has received wider consideration. It is not claimed to be a complete investigation suitable for establishing a design procedure, but results obtained provide much useful information. From author's summary

Material Test Techniques

(See Revs. 690, 704, 717, 738)

Mechanical Properties of Specific Materials

(See also Revs. 658, 690, 707, 708, 728, 730, 769, 876, 877, 880)

732. Johnson, A. E., Jr., and Semonian, J. W., A study of the efficiency of high-strength, steel, cellular-core sandwich plates in compression, *NACA TN* 3751, 26 pp., Sept. 1956.

The ratio of effective thickness to plate width is plotted against allowable loading per unit width for various ratios of facing-to-core density and for various ratios of over-all thickness to facing thickness. Curves are theoretical, and are based on short-time properties of a stainless steel at 80 F and 600 F (compressive yield strengths F_{cy} were 180,000 and 150,000 psi, respectively). Results are compared with solid plates of steel, an unidentified aluminum alloy (F_{cy} = 72,500 psi at 80 F), and an unidentified titanium alloy (F_{cy} = 140,000 psi at 80 F) by introducing the density into the ordinate parameter. The optimum steel sandwich appears to have a higher strength-weight ratio than the solid plates

except that the aluminum-alloy plate was more efficient at 80 F with loads above 2400 lbs/in. A. D. Topping, USA

733. Powell, R. W., The effect of quenching on the thermal conductivities and electrical resistivities of steel, *J. Iron Steel Inst. Lond.* **184**, 6-10, Sept. 1956.

Some preliminary experiments are described. Results are given for the effect of water-quenching on the room-temperature electrical resistivities of the series of steels previously investigated in the annealed or stabilized states. Increases of 30% or more were obtained for about half of the steels, and it is believed that the thermal conductivities would undergo comparable reductions. Measurements made on one of the steels confirm that quenching introduces similar changes in both conductivities.

Results are also included for the thermal conductivity and electrical resistivity of an annealed sample of En 31 steel, and electrical resistivity measurements are made on this steel and a 1.22% C steel after oil-quenching to temperatures in the range 135-190 C. These observations suggest that it would be feasible to make thermal conductivity determinations at 150 C on the retained austenite produced when En 31 is quenched to that temperature. The value seems likely to be of the order of 0.18 J cm/cm² s °C, compared with a value of 0.41 J cm/cm² s °C obtained for the annealed state. From author's summary

734. Powell, R. W., The effect of oil quenching and temperature on the thermal conductivities and electrical resistivities of three steels, *J. Iron Steel Inst. Lond.* **184**, 10-17, Sept. 1956.

A detailed investigation has been made of the influence of oil-quenching and tempering on thermal conductivities and electrical resistivities of three steels, En 8, En 19, and a high-C, Cr-Mo steel of En 31 type. The conductivity is reduced by O.Q., the amount of the reduction ranging from about 20% to 50% and increasing in the order in which the steels are listed. Tempering increases the conductivity and for each steel a maximum conductivity is obtained after tempering at an optimum temperature of about 100 C below the transformation temperature. Heat treatment of the annealed steel in the same temperature range also leads to similar but slower increases in conductivity, and the hardness falls a little below the low annealed value. For the tempered steel, however, the maximum conductivity can be attained while the steel retains some of the hardness due to the O.Q. This result may be of importance for certain applications of the steels.

For the various conditions, the Lorenz functions only range from 3.1×10^{-8} to 3.4×10^{-8} J ohm/s °C °K, so that the thermal conductivities can be derived to within about 5% from electrical resistivity measurements. From author's summary

735. Lula, R. A., Lena, A. J., and Johnson, H. M., Effect of cold work on elevated temperature properties of types 301, 305, and 310 stainless steels, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-44, 7 pp.

The elevated-temperature strength of AISI types 301, 305, and 310 stainless steels can be improved by cold-working provided extensive recrystallization during exposure does not take place. The rupture strength of cold-rolled materials decreases progressively with increasing recrystallization and eventually becomes poorer than that of annealed material when the amount of recrystallization exceeds 50 to 60%. It is suggested that microstructural changes which occur as a result of recrystallization account for the detrimental effect that recrystallization exerts on high-temperature strength. These include a change in grain size and redistribution of chromium carbides in types 301, 305, and 310 and the accelerated formation of sigma in type 310.

From authors' summary

736. Pattison, J. R., An analysis of the available data on the total heat of commercial steels, *J. Iron Steel Inst. Lond.* **183**, part I, 64-68, May 1956.

The available sources of data on the total heats of commercial steels are given and an attempt is made to estimate their relative value. It is suggested that the most reliable data relate to a 4% silicon steel, which has been studied over a range of temperatures including the melting point. No other data for temperatures above 1300 C, for any steel, are yet available and the existing data for the range of temperatures up to 1300 C are of unproven reliability. From author's summary

737. Forrest, G., and Gunn, K., Problems associated with the production and use of wrought aluminium alloys, *J. roy. aero. Soc.* **60**, 550, 635-658, Oct. 1956.

738. Young, A. P., Melton, C. W., and Schwartz, C. M., Study of aluminum deformation by electron microscopy, *NACA TN* 3728, 39 pp., Aug. 1956.

In this investigation, the slip-line structure in a series of aluminum single crystals deformed in tension was examined in the electron microscope. In several of the crystals the slip-line structure was examined after successive steps in the elongation.

In formulating a mechanism for slip-band formation, the experimental results of this study and of other investigations were considered. According to the proposed mechanism, slip in aluminum single crystals originates from a relatively few Frank-Read sources present before deformation in the annealed crystal. Dislocation loops are generated by these sources on a few planes of the set of parallel slip planes with the highest resolved shear stress. Frank-Read sources for slip on neighboring parallel planes are formed by the deflection of screw segments into oblique planes in a manner suggested by previous workers. The geometry of this deflection mechanism is discussed in some detail to show that it may be feasible theoretically, even when the dislocations are extended as they probably are in aluminum. The basic difference in the slip-line structure of aluminum or copper and alpha brass, as disclosed by previous workers, is accounted for by showing that, in the latter case, short-range order may prevent the deflection of screw segments. Other differences between face-centered cubic pure metals and their substitutional alloys are discussed. From authors' summary

739. Johnson, W., Experiments in plane-strain extrusion, *J. Mech. Phys. Solids* **4**, 4, 269-282, Aug. 1956.

Results of experiments in plane-strain extrusion of lead and aluminum with dies of semiangle from 30° to 90° at various reductions are presented and compared with those predicted by the use of slip-line field methods. Conclusions are drawn about the nature of the process and the predictive value of the theory. From author's summary by N. H. Polakowski, USA

740. Kurg, I. M., Tensile properties of AZ31A-O magnesium-alloy sheet under rapid-heating and constant-temperature conditions, *NACA TN* 3752, 21 pp., Aug. 1956.

Specimens of AZ31A-O magnesium-alloy sheet were heated to rupture at nominal rates of 0.2 F to 100 F per second under constant tensile load conditions. The data are presented and compared with the results of conventional tensile stress-strain tests at elevated temperatures after ½-hr exposure. A temperature-rate parameter was used to construct master curves from which stresses and temperatures for yield and rupture can be predicted under rapid-heating conditions. A comparison of the elevated-temperature tensile properties of AZ31A-O and HK31XA-H24 magnesium-alloy sheet under both constant-temperature and rapid-heating conditions is included. From author's summary

741. Kemp, W. R. G., Klemens, P. G., and White, G. K., Thermal and electrical conductivities of iron, nickel, titanium, and

zirconium at low temperatures, *Austr. J. Phys.* **9,** 2, 180–188, June 1956.

Measurements are reported of the thermal and electrical conductivities of iron, nickel, titanium, and zirconium down to 2 K. These indicate that thermal conduction in pure iron and nickel is almost completely electronic. Titanium and zirconium exhibit an appreciable lattice component of thermal conduction. In the case of titanium, this lattice component varies as $T^{1.5}$.

The ideal electronic thermal resistivity below about 50 K was found to be $10 \times 10^{-8}T^{2.2}$ and $11 \times 10^{-8}T^{2}$ cm deg W^{-1} for iron and nickel, respectively. The ideal electrical resistivity was found to vary as T^{3} at low temperatures for all four metals.

From authors' summary

742. Hanink, D. K., Wabbere, F. J., and Boegehold, A. L., Development of a new gas turbine super alloy GMR-235, *SAE Trans.* **63,** 705–716, 1955.

A new nickel-base alloy is described which offers a combination of high-temperature strength, adequate ductility, and low strategic alloy content.

Used in gas-turbine buckets where extremely high temperatures are encountered, GMR-235 has undergone a program of laboratory testing, development of foundry production and control methods, and extensive field testing with no failures.

From authors' summary

743. Aven, M. H., Craig, R. S., and Wallace, W. E., Heat capacity measurements of titanium and of a hydride of titanium for temperatures from 4° to 15° K including a detailed description of a special adiabatic specific-heat calorimeter, *NACA TN* 3787, 30 pp., Oct. 1956.

744. Lochowski, E., Heat-resisting alloys and their properties (in Polish), *Technika Lotnicza* **10,** 3, 73–81, May–June 1955.

Description of strength properties of heat-resisting alloys used in construction of jet engines.

M. Z. Krzywoblocki, USA

745. Brandes, E. A., High temperature materials—A review, *Prod. Engng.* **27,** 9, 186–190, Sept. 1956.

746. Gierdziejewski, K., and Pioskowski, J., New foundry method of metallurgical blast cupola (in Polish), *Przeglad Techn.* **76,** 4, 135–137, Apr. 1955.

747. Zartman, I. F., Effects of nuclear reactor radiations on structural materials, *Proc. Amer. Soc. civ. Engrs.* **82,** ST 2 (*J. Struct. Div.*) Pap. 918, 21 pp., Mar. 1956.

The different types of the nuclear radiations to which materials used in the construction of nuclear reactors are exposed are discussed. Conditions imposed by functional requirements are considered. The effects of nuclear radiations on the mechanical and physical properties of structural materials are discussed, experimental results are given, and basic effects considered.

From author's summary

748. Galloway, D. F., The machining properties of nonferrous metals, *J. Inst. Metals* **84,** 121–131, 1955–1956.

The increasing application in industry of new nonferrous alloys, such as the Nimonic group and titanium alloys, has given rise to new problems of machinability. These problems are being solved by techniques such as those outlined in the paper, which also presents typical research results. Descriptions of apparatus for the measurement of cutting forces and tool shape are given, and considerations influencing the design of experiments are discussed. The diversity of the machining properties of nonferrous alloys is exemplified by comparisons of cutting forces for a range of nonferrous and ferrous alloys. The combined effects of cutting speed and feed rate on tool life are shown in special charts, which indicate optimum cutting conditions. Results are given of experiments carried out to determine variations in surface finish with cutting speed, feed, cutting-tool material, and orientation of a faceted diamond tool. The concept of machinability expressed in terms of a single rating or index obtained from so-called machinability testers is discussed, and it is shown that the validity of simplified machinability tests in production practice is contingent on there being sufficient evidence of adequate correlations between the results of the tests and performance under production conditions.

From author's summary

Plasticity, Forming and Cutting

(See also Revs. 631, 727, 735, 739, 748)

749. Bland, D. R., Vector fields associated with plane plasticity, *Quart. appl. Math.* **14,** 3, 321–323 (Notes), Oct. 1956.

Starting from the equation relating a symmetric tensor with a vector field, it is found that, for the stress field in plain plasticity, associated vector fields can always be found; but conversely, it is only for certain vector fields that associated stress fields exist. Five examples of associated fields are given.

W. M. Shepherd, England

750. Hodge, P. G., Jr., Minimum principles of piecewise linear isotropic plasticity, *J. rational Mech. Analysis* **5,** 6, 917–938, Nov. 1956.

751. Ulrich, E., Addition theorem for effective stress according to the shear strain energy hypothesis and its application to hollow cylinders (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **22,** 4, 123–128, 1956.

Using principal stresses and writing the ordinary Mises second-order stress invariant as a determinant of third order, having figure one as common element of one column, it is possible to derive a super-position formula for two stress systems, developing the corresponding determinant. Theorem is applied to superposition of stress systems in a thick-walled hollow cylinder due to internal pressure and to temperature gradient. It should be noted that the two stress systems always must be coaxial which, in reviewer's opinion, should have been particularly emphasized in paper.

F. K. G. Odqvist, Sweden

Hydraulics; Cavitation; Transport

(See also Revs. 631, 714, 720, 775, 921)

Book—752. Tolke, F., editor, Publications on water-hammer problems in hydroelectric power stations and pipelines [Veröffentlichungen zur Erforschung der Druckstossprobleme in Wasserkraftanlagen und Rohrleitungen], Berlin, Springer-Verlag, 1956, v + 149 pp. DM 37.50.

A collection of five unconnected articles on various problems in water hammer.

F. Tölkes' first article gives a brief introduction of the field. The fundamental water-hammer equations are given in parametric form. This section is extremely brief and suffers from a lack of a list of symbols. Author then discusses the selection of materials for pipelines in water works service. Properties of ductile steels, manufacture of steel pipes, and the selection and manufacture of reinforced-concrete pipes are given with some detail. A well-illustrated section on various types of hydroelectric power plants follows with particular emphasis on the design of air chambers and standpipes. Finally, the common water-hammer equations are developed for simple pipelines without friction, supplied by a

nstant pressure reservoir on one end and fitted with a valve on e other. Water-hammer equations are given for sudden valve losure and for the cases in which the flow rate-time relation is near and for which it follows an elliptic cosine law.

The second article by W. Pelikan discusses the reinforcing of ater conduits by prestressed reinforced concrete and by rock rmations. While a brief theoretical approach is given, author es not believe it to be valid because of the many practical certainties in such construction. Tests to measure the einforcing effect of concrete and rock were started during the tter part of World War II and never completed. Article describes interesting polygonal chain-type strain gage to measure rcumferential expansion of pipe and some preliminary experiments the test line during filling and emptying.

A third chapter by H. Blind describes nonstationary flow in runoff ater pipes for subterranean power stations. In general, a horintal free surface exists in these runoff pipes and nonstationary henomena only raise or lower the surface. The subject is studied oth theoretically and experimentally, showing the peculiar surface hapes that arise with nonstationary phenomena. When the pipe is completely full, the flow degenerates to the common water-hammer low. Some treatment of this case is also given using the classical ethods of Allievi and Schnyder-Bergeron. The use of surge tanks runoff lines is also discussed, as is the danger of separation of e water column in the pressure conduit.

The fourth article by W. Gandenberger deals with water-hammer domestic and small-scale pipelines. Author shows experimenlly, by graphical analysis and by calculations, the relations beween surge pressure, initial head, and length of line. Surge essures can assume very high values. Subsequent simplified lculations are based on the assumption that most commercial lves control flow only during the latter stages of their closing cle. Realizing that preventive measures must be of lowest cost, suggests use of pressure reducers or friction elements just ostream of valves or the choice of smaller valves or larger ameter lines. He designs typical working charts for architects d builders based on commercial valve and line sizes.

K. Ludwig and H. Stack describe in the last chapter the design air surge chambers for water pumping stations. Authors are ncerned only with the pressure variations due to sudden pump oppage. Water is considered incompressible, pipe rigid, and air mpression isothermal. These assumptions lead to a differential uation in time which is solved rigorously and leads to direct uations for the pressure peaks and troughs. Graphical solution ethods are shown, and an example design of a surge chamber for water works is calculated in detail. A series of experiments on isting water works appears to check the calculations closely spite somewhat inadequate instrumentation during the tests.

Reviewer recommends this booklet to anyone concerned with ater-hammer since the contributions are interesting and well esented; in particular, the last three chapters.

E. G. Chilton, USA

753. Lane, E. W., Design of stable channels, *Trans. Amer. Soc. v. Engrs.* **120,** 1234–1279, 1955.

The stability of loose and cohesive materials at the surface of annel beds and banks is expressed as a function of the local ear stress. Practical design methods are given on the basis of pirical rules for the distribution of shear in trapezoidal cross ctions and of the stability of the boundary particles. The very ear and logical presentation is only insignificantly disturbed by introduction of some theoretically interesting questions which ve no practical effect on the design problems, such as whether forces dislodging solid particles are essentially lift or drag rces. The discussions point out the importance of turbulence on phases of the problem and the lack of knowledge of its influence the various phases of the stable channel problem.

H. A. Einstein, USA

754. Keifer, C. J., and Chu, H. H., Backwater functions by numerical integration, *Trans. Amer. Soc. civ. Engrs.* **120,** 429–448, 1955.

Because of the importance of nonuniform flow and the particular difficulties in computing curves in closed conduits, authors have devised new procedures facilitating backwater computations. Complete derivations of equations for computing backwater functions are presented, and adaptations of the step method are suggested as additional aids in this field. From authors' summary

755. Ippen, A. T., and Verma, R. P., Motion of particles on bed of a turbulent stream, *Trans. Amer. Soc. civ. Engrs.* **120,** 921–938, 1955.

The movement of spherical particles over a channel bed of nonuniform particles was observed. The spherical particles were glass and plastic spheres. The two types of fixed-bed material were sieved sizes of angular sand and of Ottawa sand. The adjustable-slope rectangular flume was 15 ft long by 2 ft wide. Fifty of the spherical particles were released from behind a starting wire. The average velocity of these particles along the channel was measured. The flow conditions at the beginning of movement could be readily determined in this experiment. The data did not follow the Shields' entrainment function. Two empirically determined entrainment functions, which are in agreement with the data, are presented. Data are also presented concerning established motion of the particles. In addition, valuable data are presented concerning fluid bed shear in uniform flow. Darcy's friction factor f was found to be preferable to Manning's n. The functional variation of Darcy's f with other flow parameters was rationally explained with reference to the von Karman-Nikuradse pipe-flow analysis. M. R. Carstens, USA

756. Gatwood, E. H., Nomographs aid calculation of pressure losses in hydraulic lines, *Mach. Design* **28,** 20, 113–118 (Machine Design Data Sheet), Oct. 1956.

757. Escande, L., A hypothesis in connection with surge tanks with optional throttling (in French), *C. R. Acad. Sci. Paris* **241,** 16, 1009–1011, Oct. 1955.

758. Parmakian, J., Pressure surges in pump installations, *Trans. Amer. Soc. civ. Engrs.* **120,** 697–720, 1955.

Book—759. Sitkovskii, P. A., edited by, Dictionary for irrigation and drainage engineers [Slovar-spravochnik gidrotekhnika-melioratora], Moscow, Selkhozgiz, 1955, 500 pp. $5.00.

This technical encyclopedia is intended for engineers and aids in various fields of hydraulic engineering. Over 6000 terms are explained in short articles compiled by 92 authors and 8 editors.

S. Kolupaila, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 663, 794, 806, 823, 832, 836, 868, 898, 918, 931)

Book—760. Carafoli, E., Airfoil theory for incompressible fluids [Tragflügeltheorie (inkompressible Flussigkeiten)], Berlin, VEB Verlag Technik, 1954, 562 pp.

This is a German translation (by Norbert Wass) of the Rumanian text which deals exclusively with the analytical aspects of the airfoil theory in an incompressible fluid, and is the largest and most detailed book ever published on the subject. The author worked for many years at the Aerotechnical Institute at Saint-Cyr near Paris, and has contributed much to the mathematical development of the airfoil theory. The exposition is lucid, the style of the book is elegant, and the printing is good.

Chapter 1 gives the fundamentals of classical hydrodynamics. Chapter 2 (110 pp.) gives the theory of two-dimensional wing sections. The analysis of Joukowsky airfoil, Karman-Trefftz airfoil, and Carafoli airfoil (airfoil with rounded trailing edge) is given in great details. Chapter 3 deals with theory of biplanes of infinite span. Chapter 4 deals with monoplane wings of finite span on the basis of Prandtl's lifting-line theory. Chapter 5 treats wings with flaps, ailerons, rudder, engines, etc., and steady curvilinear motions. Chapters 6, 7 discuss briefly the lifting-surface theory, with applications to wings (swept and unswept) of large aspect ratios; and wings in unsteady motion. Chapter 8 treats at length biplanes of finite span. Chapter 9 deals with wing-body interference, ground effects, etc. The last chapter, 10, treats in detail wind-tunnel wall corrections.

The author gives a fairly extensive coverage of the Russian literature, but there seems no mention of any British and American contributions published later than 1934. As a result, a great deal of important information, particularly with respect to material in chapters 4, 6, and 7, is missing. A reader seeking an up-to-date treatment of the finite-aspect-ratio wing theory or the oscillating wing theory will not find it here. Furthermore, although the author devotes about 4 pages of text and 10 pages of figures to the comparison of theory with experiment, the comparison is all too brief and inadequate.

This book is a valuable reference for students.

Y. C. Fung, USA

761. Craven, A. H., A potential flow model for the flow about a nacelle with jet, *Coll. Aero. Cranfield Rep.* 101, 46 pp. + 15 figs., Mar. 1956.

Incompressible inviscid fluid flows in two-dimensional motion round a nacelle formed by two thin airfoils equidistant from the axis of symmetry. Part of the fluid enters the nacelle at the front, receives energy, and issues at the rear as a jet. For analysis, the nacelle walls are imagined to be extended to infinity downstream along the vortex sheets (free streamlines) between jet and surrounding fluid, the jet flow being induced by suction at infinity, where the jet is parallel. The fluid passes through the nacelle without receiving energy, and the total head is everywhere constant. This idealized problem is analyzed by assuming constant vorticity along the free streamlines, and a variation of vorticity along the duct according to its shape. The imaginary extension of the nacelle supports the pressure difference across the free streamlines, and it is assumed that this difference is exactly balanced when energy is imparted to the duct fluid as in the actual case.

Results are given, with some calculations, for a two-dimensional duct and an axisymmetric duct, at zero incidence. The thick-walled duct and the duct at finite incidence are also considered.

J. F. Davidson, England

762. Marini, M., The boundary layer on rotating blades (in Italian), *Aerotecnica* **36,** 3, 218-222, June 1956.

Author establishes the equations of motion for rotating blades, starting with Navier-Stokes equation of motion for a viscous fluid, and using the expression of acceleration with reference to axis fixed to the blades. He arrives at three scalar equations and proves that the pressure is no longer constant along a normal to the surface of the boundary, as is the case for a two-dimensional case in which there are no complementary or Coriolis accelerations. Solutions for these equations have been worked out only for flow of a laminar incompressible fluid. Experimental results are scarce and the author finds them difficult to compare with theoretical values.

A. Balloffet, USA

763. Lance, G. N., Motion of a viscous fluid in a tube which is subjected to a series of pulses, *Quart. appl. Math.* **14,** 3, 312-315 (Notes), Oct. 1956.

By using Laplace transforms, it is shown that the Poiseuille flow of a viscous fluid in a pipe can be halted by subjecting the pipe to pulses of sufficient strength.

A. R. Mitchell, Scotland

764. Livesey, J. L., Parker, E., and Jones, P. K., The production of duct velocity profiles having high ratios of maximum to mean velocity, *J. roy. aero. Soc.* **60,** 546, 415-417 (Technical Notes), June 1956.

Results are presented of an investigation of a particular type of baffle for the production of symmetrical velocity profiles having high ratios of maximum to mean velocity in ducted incompressible flow. Two similar families of profiles are obtained depending on whether a short (12 diameters) or a long (48 diameters) entry length is used before the baffle. The highest value of the maximum-to-mean-velocity ratio obtained is 142 and the pressure loss coefficients associated with the use of the baffle are given together with an indication of the effect of Reynolds number.

From authors' summary

765. Higginbotham, J. T., Wood, C. C., and Valentine, E. F., A study of the high-speed performance characteristics of 90° bends in circular ducts, *NACA TN* 3696, 28 pp., June 1956.

The performance of four 90° bends in ducts of constant diameter with ratios of radius of curvature to diameter of 0.75, 1.00, 2.50, and 4.00 was investigated over a range of inlet Mach numbers extending up to the choking condition for both a thin and a thick inlet boundary layer. The variation of the measured longitudinal static-pressure gradients at low speed from those predicted by two-dimensional, incompressible, potential-flow theory was determined. It was found that an increase in the inlet boundary-layer thickness decreased the choking Mach number by a very small amount for each of the elbows and had little effect on the other performance parameters. It was concluded that, for the type of elbows tested, a mean radius-diameter ratio of approximately 2.50 would yield the greatest inlet choking Mach number with the least loss of static and total pressure.

From authors' summary

766. Craven, A. H., The free streamline method applied to the flow at the rear of a duct, *Coll. Aero. Cranfield Rep.* 99, 19 pp. + 5 figs., Mar. 1956.

Incompressible inviscid fluid issues as a jet from a duct formed by two flat plates which converge from infinity and terminate symmetrically before meeting. The jet is surrounded by fluid flowing in the same direction, the whole motion being two-dimensional and symmetrical about the duct center line. At infinity downstream the jet fluid has velocity V_2 and the outside fluid, velocity V_1. It is assumed that the velocity difference across the vortex sheets bounding the jet is $V_2 - V_1$ at all points. This assumption means that the shape of the issuing jet, determined by the Schwarz-Christoffel transformation, is unaffected by the external motion, which is calculated from the condition of constant velocity V_1 just outside the jet boundaries. This condition predetermines the conditions at infinity upstream, where the velocity just outside the duct becomes very large.

Reviewer feels that a more realistic solution would give similar velocities, for the outside fluid, at infinity in both directions. This might give a different shape of jet.

Author also considers tentatively the corresponding axisymmetric problem.

J. F. Davidson, England

767. Donoughe, P. L., Analysis of laminar incompressible flow in semiporous channels, *NACA TN* 3759, 25 pp., Aug. 1956.

Perturbation solutions of equations for laminar incompressible flow in a semiporous channel are presented, and the results are compared with those obtained from a fully porous channel. The perturbation parameter measures the amount of suction or injection

(blowing) at the porous wall; positive values denote suction, and negative values denote blowing.

In the semiporous channel, with a given value of the perturbation parameter, blowing decreased the friction parameter at the porous wall by 25%, and suction increased the wall friction parameter by 50%. For both semiporous and fully porous channels, the pressure in the longitudinal direction decreased for zero and blowing values of the perturbation parameter. Sufficiently high suction values resulted in a pressure rise in the fully porous channel. Either suction or blowing has more influence on the local dimensionless velocity profiles and the wall friction parameter for the semiporous than for the fully porous channel.

From author's summary by R. C. Roberts, USA

768. Tyabin, N. V., Unsteady flow of viscous and plastic media in round pipes (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **95,** 3, 473-475, Mar. 1954.

769. Magarvey, R. H., and Taylor, B. W., Free fall breakup of large drops, *J. appl. Phys.* **27,** 10, 1129-1135, Oct. 1956.

Some theories advanced to explain the observed drop-size distribution in natural rain involve drop multiplication due to disintegration of drops that have grown beyond the limits of stability, i,e., to shattering of large drops. This paper presents experimental results for understanding breakup phenomena associated with large drops. Drops in various stages of disintegration have been photographed and the size distribution of fragments noted. A large drop falling freely through the air deforms, inflates somewhat in the manner of a parachute, and bursts with considerable violence. The origin of various size groups of fragments and its significance in determining the observed size distribution has been noted.

An experimental arrangement is described that permits a large number of photographs to be taken of all stages of disintegration. To produce drops of uniform size, water was led to a discharge chamber from a variable, low-head reservoir. The jet issued from a discharge tube under laminar flow conditions, and was resolved into a train of uniform size drops by a periodic disturbance communicated to it through the water in the discharge chamber. Trains of uniform size drops from 2.5- to 20-mm diam were produced with the diaphragm of an earphone forming the top of the chamber. For the production of drops from 10- to 20-mm diam a plunger driven by a variable speed motor served as the source of vibrations. The drops were allowed to fall a great distance, and were photographed by Strobolume light flashes.

Clear photographs of the shattering process are included. Authors refer to the previous work of D'Albe and Hidayetulla, 1955.

K. J. DeJuhasz, Germany

770. Ingebo, R. D., Drag coefficients for droplets and solid spheres in clouds accelerating in airstreams, *NACA TN* 3762, 31 pp., Sept. 1956.

The steps preceding the burning of liquid fuel injected into a combustor, i.e., atomization, acceleration, and vaporization, are important for the design, operation, and performance of jet engines. The droplets formed by atomization simultaneously accelerate and evaporate, giving combustible fuel-air mixtures. In the present investigation, clouds of liquid and solid spheres accelerating in airstreams were studied over a range of airstream pressure, temperature, and velocity conditions. Diameter and velocity data for individual droplets and solid spheres in clouds were obtained with high-speed camera developed at the NACA Lewis Laboratory. From these data, linear accelerations of spheres (20 to 120 microns in diameter) were determined, and instantaneous drag coefficients for unsteady momentum transfer were calculated. The drag coefficients C_D for droplets (isooctane, water, and trichloroethylene) and solid spheres (magnesium and calcium silicide) were found to correlate the Reynolds number Re as given by the empirical expression:

$$C_D = 27/Re^{0.84}$$

for $6 < Re < 400$. When acceleration rates were low, the unsteady-state drag coefficients were in agreement with steady-state values from previous investigations.

From this expression for drag coefficient, an equation relating distance and time was derived for calculating trajectories of solid spheres. In the case of droplets, a graphical method was used to relate droplet diameter to distance when evaporation rates were high. At low rates of evaporation solid-sphere trajectory equations were found applicable.

K. J. De Juhasz, Germany

771. Pascucci, L., On axisymmetric gas jets at high speed and high temperature (in Italian), *Aerotecnica* **36,** 3, 234-247, June 1956.

This report recalls the principal theories on the subject, arranged according to the hypotheses made. Particular attention is paid to axisymmetric jets, discussing separately (1) a central region around the jet axis, also called the "core" of a jet or a jet in the restricted sense, and (2) a mixing region surrounding the central region and subdivided into several partial zones according to the distance from the mouth of the nozzle. For each zone are stated the working hypotheses, the equations of motion, and the resulting simplifications used to calculate the distribution of velocities and temperatures in a jet. Many of the diagrams are reprinted from the book by S. I. Pai, "Fluid dynamics of jets," D. Van Nostrand Co., New York, 1954; AMR **9,** Rev. 2249.

E. Leimanis, Canada

772. Tsukker, M. S., A laminar incompressible jet issuing from a radial diffusor along a wall (in Russian), *Prikl. Mat. Mekh.* **18,** 6, 757-761, 1954.

Consider a spinning disk or an uncased rotary impeller placed flat against a wall. The air close to the wall flows outwards along the wall, with spiral-like particle trajectories. The behavior of this jet is studied by boundary-layer techniques.

Author evaluates the leading terms in the asymptotic expansions at large radial distances for the velocity components, total mass flux, radial and angular momentum, and shearing stresses at the wall.

The radial velocity dies away more slowly than the azimuthal velocity, the mass outflow increases outward, and, if reviewer correctly interprets the results, the radial and angular momentum at a given radius vary in inverse proportion to the mass flow.

A. H. Armstrong, England

773. Koestel, A., and Austin, J. B., Jr., Air velocities in two parallel ventilating jets, *Heat. Pip. Air Condit.* **28,** 2, 137-140, Feb. 1956.

The flow pattern resulting from two close-spaced parallel air jets is described, and equations substantiated by test data are given for determining the maximum jet velocities at any distance from the nozzles. These equations will provide a designer with the means for estimating the effect of air-stream interference resulting from grilles and other outlets located near each other.

From authors' summary

774. Schmieden, C., and Muller, K.-H., Flow of a source line in the half space: an exact solution of the Navier-Stokes equation (in German), *Dtsch. Versuch. Luftfahrt E. V. Rep.* 10, 29 pp., Jan. 1956.

Navier-Stokes' equations are treated for the case of steady flow from a source line with constant density situated in the z-axis, into the half space bounded by a wall in the x, y plane. Using polar coordinates R, θ, φ and assuming the stream function in the form $\psi = R \cdot \phi(\cos\theta)$, authors deduce a Riccati differential equation for the function ϕ; this equation is transformed into a hypergeometric-differential equation. Solutions $\phi(\cos\theta)$ are discussed

which are given in a closed form as a quotient of two polynominals in cos θ. The results are in good agreement with those obtained by the boundary-layer theory by Wijngaarden in the paper: "Laminar flow in radial direction along a plane surface," *Proc. k. Ned. Akad. Wet.* **45,** 1942, but they are more general than Wijngaarden's.

J. Polasek, Czechoslovakia

775. Korvin-Kroukovsky, B. V., Forces acting on a submerged body moving under waves, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 223–243.

Author finds expressions for heaving force, the pitching moment, and the distribution of pressure forces along the length of a slender body of arbitrary shape moving under a train of waves on a path normal to the wave crests. Two-dimensional strip theory has been used, but the slope of the body surface is taken into account. Numerical computation for spheroid shows a remarkable agreement with the exact treatment of Havelock [AMR **8,** Rev. 1074].

S. D. Nigam, India

776. Stern, M., The rolling-up of a vortex sheet, *ZAMP* **7,** 4, 326–342, 1956.

Author examines problem of the two-dimensional time-dependent flow connected with the rolling up of a semi-infinite vortex sheet, studying only solutions that are homogeneous in time. Approximations to the spiral form of the rolled vortex sheet have previously been given, but it is difficult to obtain the associated flow field from these considerations. Starting with the known flow about a semi-infinite plate, and using a complex potential method, differential equations are here derived which describe the behavior of the entire flow field. Series expansions are developed that approximate to the solution in the neighborhood of the spiral core, showing essential agreement with earlier results.

G. Power, England

Compressible Flow, Gas Dynamics

(See also Revs. 808, 819, 831, 833, 838, 847, 883 884, 885, 888, 917)

777. Riparbelli, C., A principle of maximum power for real fluids in steady motion, *J. aero. Sci.* **23,** 10, 971–972 (Readers' Forum), Oct. 1956.

Author points out an analogy between elastic deformation and velocity distribution in subsonic flow. But author's opinion of a minimum energy principle only holds in slow viscous flow when inertia effects may be neglected.

F. Schultz-Grunow, Germany

778. Anderson, G. F., Aspect ratio influence at high subsonic speeds, *J. aero. Sci.* **23,** 9, 874–878, Sept. 1956.

Drag coefficients for non-lifting rectangular wings of finite span at high subsonic speeds are related to those for wings of infinite span at different speeds by using an averaged superposition process. The results allow certain experimental data for wings of finite span to be reduced approximately to common curves appropriate to infinite span. It would be interesting to know if these common curves agree with measured values for infinite span.

The superposition process involves the dubious assumption that linearized theory is valid in transonic regimes at some distance from the sources of disturbance, for although the linearized equations of motion are valid there, their solutions, based on boundary conditions at the sources of disturbance, are not. Presumably the subsequent averaging, which is also of dubious validity, causes some cancelling of errors, because the experimental data reduces well on this theory, the results of which seem to have some empirical value.

G. N. Ward, England

779. Anonymous, Tables of aerodynamic coefficients for an oscillating wing-flap system in a subsonic compressible flow, *Nat. LuchtLab. Amsterdam Rap.* F. 151, 33–58, May 1954.

Report contains the numerical results for the aerodynamic coefficients of an oscillating wing-flap system, where the flap hinge axis coincides with the flap nose. The complete set of 9 complex coefficients is given for the Mach numbers $\beta = 0.35, 0.5, 0.6, 0.7, 0.8$. The ratio of flap to wing chord is 0.1, 0.2, 0.3. Exact calculations have been made for 9 or 10 values of the reduced frequency ω in case of the wing coefficients and for 7 or 8 ω values in case of the flap coefficients. Interpolated values are presented for $\omega = 0\ (0.02)$, 0.90 if $\beta = 0.8$, and for $\omega = 0\ (0.02)$, 1 for all other β-values.

From summary

780. Rethorst, S., Lift on a wing in a propeller slipstream as related to low-speed flight, *Aero. Engng. Rev.* **15,** 10, 42–48, Oct. 1956.

Analytic solution for thin wing giving close agreement with experiment described. Mathematical details are omitted.

C. Ablow, USA

781. Jones, R. T., Some recent developments in the aerodynamics of wings for high speeds, *Z. Flugwiss.* **4,** 8, 257–262, Aug. 1956.

Discussed in this summary paper are (1) a recently proposed correction formula for the effect of compressibility in two-dimensional subsonic flow, (2) the equivalence rule and the area rule for transonic speeds, (3) reciprocal relations in linearized wing theory, and (4) some general results connected with the problem of minimum wave resistance. The paper concludes with an example showing indentation of the fuselage to obtain favorable interference with the wing at supersonic speeds.

From author's summary

782. Germain, P., Remarks on the theory of partial differential equations of mixed type and applications to the study of transonic flow, *Comm. pure appl. Math.* **7,** 1, 117–143, Feb. 1954.

Author recalls briefly some well-known statements on problems arising in theory of transonic flow. These are related mathematically to partial differential equations of the mixed type. Second part is devoted to formation and study of elementary solutions of this type; a few applications to certain boundary-value problems are proposed, e.g., Tricomi's problem.

From author's summary by H. M. Voss, USA

783. Wood, G. P., and Gooderum, P. B., A factor affecting transonic leading-edge flow separation, *NACA TN* 3804, 43 pp., Oct. 1956.

A change in flow pattern that was observed as the free-stream Mach number was increased in the vicinity of 0.8 was described in *NACA TN* 1211 by Lindsey, Daley, and Humphreys. The flow on the upper surface behind the leading edge of an airfoil at an angle of attack changed abruptly from detached flow with an extensive region of separation to attached supersonic flow terminated by a shock wave. In the present paper, the consequences of shock-wave boundary-layer interaction are proposed as a factor that may be important in determining the conditions under which the change in flow pattern occurs. When the Mach number is high enough, the attached-flow pattern exists because then the shock wave is far enough behind the leading edge to keep the influence of the high pressure behind the shock wave from extending through the boundary layer to the immediate vicinity of the leading edge and affecting the flow there. Some experimental evidence in support of the importance of shock-wave boundary-layer interaction is presented.

From authors' summary

784. Billington, I. J., An experimental study of the one-dimensional refraction of a rarefaction wave at a contact surface, *J. aero. Sci.* **23,** 11, 997–1006, Nov. 1956.

The piezo-electric gage, hot wire anemometer, and schlieren drum camera have been used to investigate the shock-tube rarefaction wave and the interaction of this wave with a presumed stationary gaseous interface. Shock-tube rarefaction is found to deviate appreciably from ideal theory, as shown by Mack from density measurements [*Lehigh Univ. Inst. of Res., Tech Rept.* 4, 1954]. Most measured flow variables for wave interaction are found in fair agreement with theory if incident wave is described by experimentally determined quantities. However, data presented indicates that reflected rarefaction or compression waves are only about one-half as strong as predicted. Author does not comment on this point. R. E. Duff, USA

785. Naylor, D., Unsteady simple waves in gases, *J. rational Mech. Analysis* **5,** 4, 687–714, 1956.

Particular exact solutions are obtained for the quasi-linear potential equation of unsteady, two-dimensional, ideal, compressible flow. These solutions are generalizations of the "simple waves" of steady-flow theory. The analysis involves use of the hodograph method and the Legendre contact transformation. Several special cases are discussed.

S. A. Schaaf, USA

786. Chernyi, G. G., One-dimensional unsteady motion of a perfect gas with a strong shock wave (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **107,** 5, 657–660, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 6 pp.).

Solution to title problem is presented as a power series in $\epsilon = (\gamma - 1)/(\gamma + 1)$, γ being the ratio of specific heats. Method is based on assumption that the density upstream of the shock is much greater than that of the undisturbed gas and that its gradient is small in this region.

Specific problem of self-similar motion of a shock, initiated by the motion of a piston, moving into a gas at rest is solved. Piston motion is proportional to the $(n + 1)$ power of time, where n is a constant. Variation of ratio of pressure at piston to that just upstream of shock is found as a function of n. Comparison with numerical solutions of differential equations obtained by various Russian investigators shows good agreement. Density variation shows, however, that basic assumption is not valid for negative values of n. H. E. Brandmaier, USA

787. Rott, N., Diffraction of a weak shock with vortex generation, *J. fluid Mech.* **1,** 1, 111–128, May 1956.

The problem of diffraction of a weak shock by a wedge is treated by dividing the potential into a vortex-free part ϕ_s and an additional part ϕ_Γ due to the existence of the vortex sheet originating at the edge. Dimensional arguments determine the dependence of the circulation, the coordinates of the center of the spiral, and the velocity of the center upon the Mach number of the flow behind the incident wave. The results depend upon the fact that, for weak pulses, the vortex region is "generated and dominated" by the first term in the expansion of ϕ_s in powers of distance from the leading edge.

The vorticity region is next replaced by a single concentrated vortex. This vortex is not free. Following Brown and Michael [AMR **9,** Rev. 229] and Edwards [AMR **8,** Rev. 181], author supposes that the vortex is subject to a Joukowsky force cancelling the unbalanced force on the vertex-vortex line arising from the variable circulation. Reasonable agreement between theory and experiment inferred at this stage is removed (particularly for blunt wedges) when the Kutta condition (finite velocity at the sharp edge), which makes the motion completely determinate, is applied. There follows a discussion of the ineffectiveness of the Kutta condition, in particular of its connection with the secondary vortexes observed in shadowgrams.

Finally, a short account is given of the theory of the core of a spiral vortex sheet in a perfect fluid. D. C. Pack, USA

788. Drell, H., and Sedgwick, T. A., Induction system selection, *Aero. Engng. Rev.* **15,** 11, 67–75, Nov. 1956.

A study of merits of supersonic air induction systems for jet engines. Two types are treated: those in which oblique shock compression occurs ahead of the actual inlet and those for which it is internal. Two-dimensional and conical systems are studied in speed range $1.5 < M < 4$. External compression is in general use because of shorter channel length, better flow stability, and ease in starting. Above $M = 2$, authors put forth stray arguments for reconsidering internal compression inlets. Chief reason is the inordinately large wave drag produced by the cowling of external compression inlet at higher M. Speed and range calculations are made to bear out this contention. W. Griffith, USA

789. Riabouchinsky, D., Existence criteria of solutions of equations describing the nearly linear unsteady measurement of perfect compressible fluids (in French), *C. R. Acad. Sci. Paris* **241,** 16, 1012–1014, Oct. 1955.

790. Bernard, J. J., Contribution to the kinetic theory in one-dimensional flow (in French), *ONERA Publ.* 79 pp., 1955.

Because a Maxwellian distribution is in principle inapplicable to gas flows with strong temperature and velocity gradients author synthesizes other distributions for use in the solution of Boltzmann's equation. The particular distributions lead to more tractable expressions for the equations of motion, and application to shock waves is possible. Calculations of shock-wave thicknesses as a function of Mach number for the monatomic gas argon, treated as a spherical molecule, show good agreement with experiment. Author claims that the synthetic distributions give reasonable representation of the statistical state of the gas in a shock wave, based on the approximate solution of the nonlinear Boltzmann equation. Suggestion is made that extension of treatment to more complex gas or gas mixtures will not involve excessive complication. M. Gilbert, USA

791. Holt, M., and Blackie, J., Experiments on circular cones at yaw in supersonic flow, *J. aero. Sci.* **23,** 10, 931–936, Oct. 1956.

A study has been made of the pressure field on the surface of yawed cones. Experiments at Mach number 3.53 were conducted with 15° and 20° cones at yaw angles to 25°. To compare measured data with existing theory, results of three methods of calculation are presented: A first-order theory of Stone for supersonic flow at small yaw angles; a correction due to Ferri to account for entropy distribution around cone; and a second-order theory due to Kopal.

For azimuth angles on the cone, intermediate to the plane of symmetry of flow, the entropy correction merely improves the theory at small angles of yaw, otherwise the first-order calculations are to be preferred. However, the second-order theory gives, by far, the best agreement over the entire range of the experiments.

Presentation of experimental lift and drag coefficients is also made, although details of the method are not indicated. The second-order theory again is in best over-all agreement with experiment. The entropy correction appears to agree with the drag data at small yaw. However, the first-order calculation gives better agreement for lift and for drag at higher yaw.

It is stated that the entropy correction is of value for cones of moderate vertex angle, at small yaw, and it is presumed that "moderate" refers to cone angles other than tested in this presentation. It is concluded that the viscosity effect on pressure distribution is not important on cones in high Mach number flow.

H. M. Spivack, USA

792. McLean, F. E., and Rennemann, C., Jr., Supersonic flow past nonlifting bumped and indented bodies of revolution, *NACA TN* 3744, 39 pp., Sept. 1956.

Linear theory is used to calculate surface pressures, field pressures, and wave drag of nonlifting bumped and indented bodies of revolution. The results are compared with the corresponding properties of a smooth basic body. Relatively small surface irregularities are shown to cause large pressure disturbances both on the body and in the field; these being such that the wave drag increases regardless of whether volume is added to or subtracted from the basic body. Since viscous effects would tend to reduce the magnitude of the calculated disturbances, these results provide a method which is somewhat conservative for obtaining a rapid estimate of the wave drag of slender, nonsmooth bodies of revolution. H. A. Stine, USA

793. Wu, T. Y., Small perturbations in the unsteady flow of a compressible, viscous and heat-conducting fluid, *J. Math. Phys.* **35,** 1, 13–27, Apr. 1956.

The unsteady flow of a compressible, viscous and heat-conducting fluid resulting from small disturbances in external forces and heat additions is studied by means of the linearized theory. Concepts of longitudinal and transversal waves are generalized to include heat conduction. Asymptotic solutions at large and small values of time are obtained in closed forms for one-dimensional longitudinal waves, both spherical and plane, for the case where the Prandtl number is 3/4. It is shown that, when time is small, simple diffusion about the origin is the main process while, for time large, diffusion about the propagating sound waves becomes important. T. Y. Toong, USA

794. Oswatitsch, K., A generalization of the potential of a vortical flow (in German), *Öst. Ing.-Arch.* **10,** 2/3, 239–241, 1956.

A generalized potential function Φ is introduced with the velocity vector $\mathfrak{W}$ in the form: grad $\Phi = f(x, y, z)$. $\mathfrak{W}$, where f is a scalar function of the space coordinates not yet determined. For irrotational flow, f is equal to unity and Φ is the velocity potential in the ordinary sense. Author determined f for incompressible vortex flow and also for viscous flow. He extended it to some type of compressible flow. M. Sanuki, Japan

795. Lee, J. D., The induction of flow by an injector nozzle, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 355–370.

Analysis treats case of injector nozzle discharging into constant-area duct. General equation, based on constancy of mass, momentum, and energy, covers either subsonic or supersonic velocity of primary, secondary, and mixture flows; second law of thermodynamics (entropy increase) determines physically possible solutions. Cases chiefly studied are: (1) supersonic primary and subsonic secondary and mixture flows. (2) supersonic primary and zero secondary flow (free-jet wind tunnel). Plots show extent of agreement between theory and test for these cases. C. W. Smith, USA

796. Kronsbein, J., Fluid motion in a circular vortex ring, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 315–327.

Fluid motion in a circular vortex ring, whose cross-sectional diameter is not assumed small, is generated from the velocity field induced by the diametral group (a subgroup of the full inversion group of 3-space). This velocity field renders identically zero the viscosity term in the Navier-Stokes equation of motion which therefore reduces to that of inviscid flow. A suitable law of fluid density is then inferred from the equation of continuity. L. M. Milne-Thomson, USA

797. Lance, G. N., and Deland, E. C., The steady, axially symmetric flow of a viscous fluid in a deep rotating cylinder which is heated from below, 1955 Heat Transfer and Fluid Mech. Inst., Univ. Calif., Los Angeles, June 23–25, 1955. Pap. 16, 16 pp.

Authors present perturbation solutions of the linearized steady-state equations of heat conduction and motion describing the motion of a viscous compressible fluid in a rotating cylinder slowly heated round the lower rim and cooled near the center of the base. The method is an extension of that used by T. V. Davies [*Phil. Trans. roy. Soc.* (A) **246,** 81–112, 1953]. Three depths are considered, small (as considered by Davies) and two depths comparable with the radius of the cylinder. Values are computed for rotation Reynolds numbers (R) in the range 0 to 64.

Results show that a meridional circulation is set up with outflow near the base and downflow along the axis, with corresponding zonal velocities; as the depth increases, velocities become much smaller and less sensitive to changes in R.

The adaptation for a differential analyzer of the set of simultaneous ordinary differential equations with two-point b.c's is an interesting subsidiary aspect of the paper. R. P. Pearce, Scotland

798. Grodzovskii, G. L., and Kuznetsov, Yu. E., Gas-flow vortex-cooling-chamber theory (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 10, 112–118, Oct. 1954.

Ideally analytical study of solid body motions of a compressible gas in so-called "vortex cooling tube." Pressure, density, and temperature distribution as a function of the radial distance are calculated for the adiabatic case. Difference of the viscous layers in the neighborhood of the cylindrical walls is found to be significant but is not accounted for in the calculations. Method of improving efficiencies of the vortex tube is discussed. V. Korolenko, USA

799. Yasuhara, M., On the hypersonic viscous flow past slender bodies of revolution, *J. phys. Soc. Japan* **11,** 8, 878–886, Aug. 1956.

Solutions are presented for the characteristics of the laminar boundary layer about slender bodies of revolution in hypersonic flow. The procedure is similar to that used by Stewartson [AMR **9,** Rev. 805] to solve the equivalent problem on the flat plate. Stewartson's work is thus extended to the case of slender bodies of revolution and numerical results given for the case where the radius of the body is proportional to the 3/4 power of the axial distance. L. H. Schindel, USA

800. Pan, L. J., and Kuo, Y. H., Compressible viscous flow past a wedge moving at hypersonic speeds, *J. Math. Phys.* **35,** 2, 179–193, July 1956.

Problem considered is to find the effect on the flow of entropy or vorticity generated by the shock. Previous viscous theories for thin sharp-nosed bodies have neglected this effect.

The "external" field is determined by a perturbation from uniform flow and the boundary layer is found in the usual manner. These two flow fields are then matched. Discussion points out that boundary-layer solutions consistent to first order cannot be obtained in manner presented in paper but that conclusions are valid to order $\epsilon^{1/2} = (C/Re)^{1/4}$, where C is a constant and Re is the Reynolds number. The conclusion is that the entropy generated and the waves reflected by the leading-edge shock play only a minor role in influencing the flow and can be neglected at hypersonic Mach numbers. S. Ostrach, USA

801. Chernyi, G. G., Hypersonic gas flow around a body (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **107,** 2, 221–224, 1956 (translated from Russian by M. D. Friedman, 572 California St., Newtonville 60, Mass., 6 pp.).

It was long ago pointed out by von Karman, and now a well-known result, that in inviscid hypersonic flow the layer between the shock wave and the body contours tends to zero if the ratio of specific heats γ is taken to be unity. Author formulates a first-order approximation by expanding the solution in a power series of the small parameter $\epsilon = (\gamma - 1)/(\gamma + 1)$, using the distance along the body contour and the stream function as independent variables,

for both two-dimensional and axisymmetric motions. As an example, the hypersonic flow around a truncated cone with a duct is calculated. The result is then specialized to the cases of cone and wedge and compared with known exact solutions.

An almost identical approach appears to have been followed by M. J. Lighthill and his coworkers in treating the problem of detached shock in front of a blunt body in hypersonic flow, as reported in a lecture delivered by Lighthill at the Institute of the Aeronautical Sciences, Washington, D.C., at the end of September 1956. The simultaneous but independent discovery of the same idea is worth noting. S. F. Shen, USA

802. Pai, S. I., and Shen, S. F., Hypersonic viscous flow over a wedge, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 259–272.

Generalized Karman integral method for compressible boundary-layer equations is used to avoid separate treatment of "interaction" regions. Skin friction, heat-transfer coefficient, and induced pressure distribution due to interaction of inviscid and boundary-layer flows are calculated. Brief comparison of these results with those of other theories and experiments are presented. Analysis is restricted to region where boundary-layer assumptions are valid.

The interaction phenomenon is found to have profound effects on the skin friction, induced pressure distribution, and heat-transfer coefficients. S. Ostrach, USA

803. Gessner, E., Nomograph for designing gas nozzles and orifices, *Prod. Engng.* **27,** 10, 141–143, Oct. 1956.

Alignment chart gives weight of flow if pressure ratio, upstream pressure, and orifice diameter are known.

From author's summary

Wave Motion in Fluids

(See Rev. 785)

Turbulence, Boundary Layer, etc.

(See also Revs. 762, 799, 835, 837)

804. Smith, A. M. O., Rapid laminar boundary-layer calculations by piecewise application of similar solutions, *J. aero. Sci.* **23,** 10, 901–912, Oct. 1956.

Unlike most boundary-layer papers, this has the merit of being useful. In a general sense, the author's method is similar to the Karman-Pohlhausen scheme. He assumes a considerable amount of semiempirical information—such as taking the boundary-layer profiles as members of the Falkner-Skan family—and sets up equations while forcing agreement among the pertinent quantities. The paper is distinguished by ingenious use of existing information, and the method is justified by its results and its simplicity. The calculation procedure is set forth clearly, and aids to calculation are given in the form of graphs; a sample calculation is shown, and several results of the procedure are compared with others that might be logically considered as more satisfying and elegant.

As the author has suggested, this procedure could well be applied to cases involving compressibility and heat transfer.

R. Stevenson, USA

805. Pai, S. I., On the boundary-layer equations of a very slender body of revolution, *J. aero. Sci.* **23,** 8, 795–796 (Readers' Forum), Aug. 1956.

Author indicates that if the transformation equations already used by Probstein and Elliott [AMR **9,** Rev. 2621] and R. M. Mark [GALCIT, Hypersonic Wind Tunnel Mem. 21, July 1954] are augmented by a redefined enthalpy function and the assumption $P_r = 1$, then the axisymmetric problem takes exactly the form of the classical, two-dimensional boundary-layer problem. Thus methods appropriate to solve this problem may be applied to that of the slender projectile. F. D. Bennett, USA

806. Geis, T., "Similar" three-dimensional boundary layer (in German), *J. rational Mech. Analysis* **5,** 4, 643–686, 1956.

Let u and v be velocity components parallel to the wall. Author considers the conditions for which the profiles of the component u are the same at all points of the wall, except for a scale factor that depends on the location of the wall, the same being true for the profiles of the component v. In this case, the governing equations are reduced to a system of two ordinary nonlinear differential equations of the third order with constant coefficients.

The conditions for similarity are expressed as a system of partial differential equations for the velocity components of the "outside" flow, the metric properties of the wall and of the coordinate system. Several solutions of this set of partial differential equations are presented which show that the present theory unifies in an elegant manner particular cases of similar two- and three-dimensional boundary layers that are known from the literature. H. G. Loos, USA

807. Fettis, H. E., On the integration of a class of differential equations occurring in boundary-layer and other hydrodynamic problems, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 93–114.

Author presents a method for the integration of a class of differential nonlinear equations with assigned boundary conditions at infinity as well as at the origin. This method appears very good in many equations occurring in boundary-layer problems and other questions. Solution is developed in a series in which a first part, "asymptotic", satisfies the differential equation for the condition at infinity, but does not meet the initial condition; a second part, "indicial solution", satisfies a homogeneous linear equation and all boundary conditions (at infinity and at the origin); the remainder vanishes at infinity and at the origin and serves to bring the solution closer to that of the differential equation. A convergence criterion for the series would be desirable. G. Sestini, Italy

808. Persh, J., A theoretical investigation of turbulent boundary layer flow with heat transfer at supersonic and hypersonic speeds, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 143–161.

A theoretical investigation of compressible turbulent boundary-layer flow with and without steady-state heat transfer has been conducted. This investigation is based on a simple physical model of the flow suggested first by Prandtl and used later by Donaldson. The physical model consists of a laminar sublayer region with a linear velocity profile and an outer turbulent portion with a power law velocity profile. Comparisons between theory and experiment demonstrate that the analysis yields good results.

From author's summary By A. von Baranoff, France

809. Witt, W. R., Jr., Free flight boundary layer transition studies on cones, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, pp. 297–313.

An extensive program is underway at the Naval Ordnance Laboratory to determine the effects of Mach number, cone angle, Reynolds number per foot, roughness, nose bluntness, heat transfer, and angle of attack on the transition of the boundary layer from

laminar to turbulent flow. Results from the first phase of this program are presented in this paper.

Highly polished (1 to 2 micro-inch surface roughness) cones with 10-degree total angle were fired in the Pressurized Ballistic Range. Transition has been found to occur at Reynolds numbers varying from 1 million to 21 million and is strongly dependent on angle of attack. A cone with a rougher surface (from 8 to 10 micro-inch) and with a slightly blunted tip (0.0625-in. diam) yielded the same Reynolds number of transition as the very smooth cone. However, the rough cone did not yield the low values of transition Reynolds number that were obtained with the smooth cone. These results are in agreement with the theory of Dorrance and Romig which predicts that blunting the nose of the cone will significantly reduce the local Reynolds number, particularly for low semi-vertex angle cones. G. Nothwang, USA

810. Eckert, E. R. G., Schneider, P. J., and Koehler, F., Mass transfer cooling of a laminar air boundary layer by injection of a light-weight gas, *Univ. Minn. Inst. Technol., Mech. Engng. Dept. TN Rep.* 8, 24 pp., Apr. 1956.

Calculations are presented for mass transfer cooling of a laminar air boundary layer by injection of hydrogen. All properties in the binary boundary layer are considered to vary with local mixture concentration and local mixture temperature. Results in the form of boundary-layer velocity, concentration, and temperature profiles are given for a particular free-stream air temperature of 392 F, a free-stream Mach number of 12, a surface-to-free-stream temperature ratio of 6, and surface concentrations of 0, 0.2, 0.4, 0.6, 0.8, and 0.9. The injection rate and skin friction are presented as a function of the surface concentration.

From authors' summary by K. M. Siegel, USA

811. Eckert, E. R. G., and Schneider, P. J., Diffusion effects in a binary isothermal boundary layer, *Univ. Minn. Inst. Technol., Mech. Engng. Dept. TN Rep.* 5, 20 pp., Apr. 1956.

Adequate control and reduction of surface temperatures are rapidly becoming critical considerations in the successful design and development of high-speed vehicles. Recent studies suggest that the effects of aerodynamic heating can be substantially reduced by injection of a properly selected gas from the surface into the high-speed boundary-layer air. The present study is directed toward a quantitative evaluation of this mass-transfer cooling method.

Similarity solutions have been obtained for plane longitudinal flow over a flat porous plate with normal injection of a fluid whose variable properties are widely different from those of the main stream. Variation of properties with mixture temperature and concentration are evaluated from results of molecular theory. Particular boundary-layer calculations are performed by the method of successive approximations for hydrogen injection into an air boundary layer under isothermal conditions. Calculated skin-friction coefficients are compared with corresponding values for the case of constant-property diffusion.

From authors' summary by K. M. Siegel, USA

812. Piercy, N. A. V., Richardson, E. G., and Winny, H. F., On the convection of heat from a wire moving through air close to a cooling surface, *Proc. phys. Soc. Lond.* (*B*) **69,** 439, 731–742, July 1956.

L. V. King's well-known theoretical solution is extended here to include wall correction. The wall effect is represented by images. Authors predict that the extra heat loss due to the wall proximity diminishes with the increase of the Péclet (Reynolds) number of the flow around the wire; therefore using the still air wall effect for correcting hot-wire measurements is misleading. The theoretical prediction for the percentage increment of heat loss due to wall proximity has been experimentally verified.

L. S. G. Kovasznay, USA

813. Richardson, E. G., The correction of hot-wire readings in a boundary layer for proximity to the solid boundary, *J. aero. Sci.* **23,** 10, 970–971 (Readers' Forum), Oct. 1956.

This short note summarizes the main points of a more extensive publication (See preceding review). The proximity of a wall increases the hot-wire heat loss by an amount depending on the Péclet number. The effect on measuring boundary-layer mean velocity profiles is shown in a figure.

L. S. G. Kovasznay, USA

814. Van Driest, E. R., On turbulent flow near a wall, *J. aero. Sci.* **23,** 11, 1007–1011, 1036, Nov. 1956.

815. Lee, Dorothy B., and Faget, Maxine, A., Charts adapted from Van Driest's turbulent flat-plate theory for determining values of turbulent aerodynamic friction and heat-transfer coefficients, *NACA TN* 3811, 16 pp., Oct. 1956.

A modified method of Van Driest's flat-plate theory for turbulent boundary layer has been found to simplify the calculation of local skin friction coefficients which, in turn, have made it possible to obtain through Reynolds analogy theoretical turbulent heat-transfer coefficients in the form of Stanton number. A general formula is given and charts are presented from which the modified method can be solved for Mach numbers 1.0 to 12.0, temperature ratios 0.2 to 6.0, and Reynolds numbers of 0.2×10^6 to 200×10^6. M. S. Uberoi, USA

816. Sandborn, V. A., Summary of turbulence measurements in the NACA Lewis 6- by 60-inch boundary-layer channel, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 1–22.

Paper is a summary of author's previous work [AMR **7,** Rev. 1196; **8,** Revs. 2072, 3134]. Measurements of mean and fluctuating velocities, turbulent spectra and shear were made in a turbulent boundary layer with zero and adverse pressure gradients. Results are compared with empirical relations for skin friction and separation. Local isotropy is found to exist in the outer part of the boundary layer. M. S. Uberoi, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 760, 778, 830, 834, 839, 840, 841, 843, 916)

817. Diederich, F. W., The dynamic response of a large airplane to continuous random atmospheric disturbances, *J. aero. Sci.* **23,** 10, 917–930, Oct. 1956.

The analysis of the response of an airplane to a one-dimensional random gust is extended to cover the case of a two-dimensional gust. The turbulence is assumed to be axisymmetric so that the two-dimensional correlation function can be simply expressed in terms of the one-dimensional function.

Mean square responses are calculated assuming that the atmospheric turbulence can be represented by Liepmann's correlation function. Comparing the effect of gust variation along the span with the one-dimensional case, results indicate that (a) the mean-square normal load factor is reduced by an amount which depends on the aspect ratio and the scale of turbulence, (b) for a wing, the mean-square-root bending moment is reduced if most of the airplane mass is in the fuselage, but is increased if most of the mass is in the wing, (c) for large airplanes, the rolling acceleration due to spanwise variation in vertical gusts may be significant.

D. Young, USA

818. Drischler, J. A., Calculation and compilation of the unsteady-lift functions for a rigid wing subjected to sinusoidal gusts and to sinusoidal sinking oscillations, *NACA TN* 3748, 59 pp., Oct. 1956.

The total lift responses of wings to sinusoidal gusts and to sinusoidal vertical oscillations are calculated from the response to gust penetration and to a sudden change in sinking velocity through use of the well-established reciprocal relations for unsteady flow. The cases considered are two-dimensional wings in incompressible, subsonic compressible, sonic, and supersonic flow; elliptical and rectangular wings in incompressible flow; wide rectangular and delta wings in supersonic flow; and delta wings of vanishingly low aspect ratio in incompressible and compressible flow. For most of the cases considered, closed-form expressions are given, and the final results are presented in the form of plots of the square of the modulus of the lift coefficient for wings in a sinusoidally oscillating gust and in the form of the real and imaginary parts of the lift component for wings undergoing sinusoidal sinking oscillations.

A summary table is presented as a guide to the scope and results of this paper; this table contains the figure and equation numbers for the types of flow and planforms considered.

From author's summary by W. P. Jones, England

819. Fowell, L. R., Exact and approximate solutions for the supersonic delta wing, *J. aero. Sci.* **23,** 8, 709–720, 770, Aug. 1956.

In order to obtain a deeper insight into the nature of more general conical flows and to determine the errors caused by the neglect of nonlinearity, an exact solution has been given of the equations governing steady inviscid supersonic flow with constant stagnation enthalpy about an infinitely thin flat delta wing with supersonic leading edges at a finite angle of attack and zero angle of yaw. Two solutions exist for the flow over the expansion surface; below some critical angle of attack a continuous solution can exist, while above that angle the solution must be discontinuous. As to the continuous solution, the region of influence of the wing apex is determined analytically and the exact solution outboard of this region is given in a closed form, while the solution within is found by relaxation processes. For the discontinuous case, an approximate method is suggested in which the discontinuity takes the form of a conical shock, whose presence is also experimentally verified. The theoretically predicted and experimentally measured pressure ratio across the shock agree within 5%.

No sudden transition from a continuous to a discontinuous flow field was noted. The experimental results show the shock wave to be established at relatively low angles of attack, increasing in strength as the angle increases. The strength of this inboard shock is an effect of second order or smaller in magnitude.

For the flow over the compression surface the boundaries of the region of influence of the wing apex, except the shock segments, are obtained analytically and the solution outboard of this region is given in closed form, while the solution within is determined by relaxation processes, involving an iteration procedure for the location of the curved shock portion of the boundary of the region of influence of the wing apex. The region of nonzero entropy gradients is determined and the rotationality effect is calculated, the latter appearing to be very small; a singularity in the entropy along the wing centerline is established. These exact solutions for the supersonic delta wing can be approximated very closely by means of a simple adjustment of the linearized solutions; moreover, this indicates the interesting fact that the main part of the error made by the linearized solutions is due to the approximation of the boundary conditions in the inboard region rather than to the approximation of the governing equations.

The linearized and the exact theory are applied to an example and the errors of the linearized theory, e. g., in the pressure, appear to be very serious, but, being of opposite sense on the two wing surfaces, the total lift of the delta wing is approximated in a very satisfying manner by the linearized theory.

E. M. de Jager, Holland

820. Croom, D. R., Shufflebarger, C. C., and Huffman, J. K., An investigation of forward-located fixed spoilers and deflectors as gust alleviators on an unswept-wing model, *NACA TN* 3705, 26 pp., June 1956.

An investigation was made in the Langley 300 mph 7- by 10-ft tunnel and the Langley gust tunnel to determine the static longitudinal aerodynamic characteristics and the gust-alleviation capabilities of forward-located (at 12% chord) fixed spoilers, deflectors, or a spoiler-deflector combination on a simulated transport airplane model having an unswept wing.

The lift-curve slopes are fairly linear and are substantially reduced by the addition of either the spoiler or deflector configuration; however, the lift-curve slope was nonlinear for the spoiler-deflector combination. Extending the deflectors necessitates only small changes in attitude and trim in order to maintain a given lift coefficient, whereas extending the spoiler or the spoiler-deflector combination requires large changes.

Both the spoiler and the deflector configurations appear to be effective in reducing the normal acceleration in both an up gust and a down gust. It would appear from the gust-tunnel and wind-tunnel tests reported that a forward-located fixed deflector would be a practicable and effective alleviator of gust loads on an airplane having unswept wings when turbulence is encountered, inasmuch as it reduces the normal accelerations, aids in slowdown to rough-air speed, and requires only small trim changes.

Preliminary results obtained in the Langley 300 mph 7- by 10-ft tunnel on a model having a 35° sweptback wing have indicated that deflectors, to have the same effectiveness as reported for the unswept-wing model, would have to be located more rearward on the swept wing and would possibly require larger projections.

From authors' summary

821. McBride, E. E., Preliminary investigation of the effects of external wing fuel tanks on ditching behavior of a sweptback-wing airplane, *NACA TN* 3710, 21 pp., July 1956.

An experimental investigation was made by use of a 1/10-scale dynamically similar model of a typical sweptback-wing airplane equipped with external wing fuel tanks to determine the effects of the tanks on the ditching behavior. Tanks of various fuel capacity (206, 260, and 450 gallons full-scale) and with several shape modifications were used. The model was landed in calm water at the Langley tank no. 2 monorail.

The ditching behavior of the model, both with and without tanks, was determined from visual observations, acceleration records, and motion picutres of the ditchings. Data are presented in tabular form, time-history curves of acceleration and attitude, and sequence photographs.

From the results of the investigation, it is concluded that streamline tanks with circular cross section have a detrimental effect on the ditching behavior because of the suction forces generated on such shapes when planing on the water. Such tanks should, therefore, be jettisoned before a ditching is attempted. Tanks having their cross section modified by the addition of either chine strips or dead rise with chines improved the ditching behavior of the airplane model. Before an attempt is made to incorporate such modifications in a full-scale airplane, however, consideration must also be given to providing a structural design that would withstand the water loads.

From author's summary

822. Gebhard, D. F., and Goland, L., On the damping in pitch of a helicopter rotor in forward flight, *J. aero. Sci.* **23,** 11, 1051–1052 (Readers' Forum), Nov. 1956.

An expression is developed for the rotor contribution to the derivative of pitching moment with respect to pitching velocity. Results for the variation of this derivative with advance ratio are compared with similar results using a simpler expression given in

NACA TN 2136, and show substantially higher values at increasing values of advance ratio. G. Isakson, USA

823. Gessow, A., Equations and procedures for numerically calculating the aerodynamic characteristics of lifting rotors, *NACA TN* 3747, 21 pp., Oct. 1956.

Equations and procedures are presented for carrying out the numerical operations involved in computing the aerodynamic characteristics of lifting rotors by means of modern high-speed automatic computers. The characteristics considered include the thrust, profile drag, total power, flapping, rolling and pitching moments, direction of the resultant-force vector, and the harmonic contribution of the shear-force input to the hub. The equations are general and can account for stall and compressibility effects, hinge offset, and other factors that are normally omitted from conventional analytical rotor treatments.

From author's summary by T. P. Torda, USA

824. Makofski, R. A., Charts for estimating the hovering endurance of a helicopter, *NACA TN* 3810, 15 pp., Oct. 1956.

As a means of comparing the performance capabilities of various helicopter propulsion systems, charts have been presented for estimating the hovering endurance of a helicopter in the form of a hovering-endurance parameter as a function of the ratio of total fuel load to helicopter initial weight for a range of initial thrust coefficients from 0.002 to 0.012 and for values of rotor-mean-lift coefficient from 0.24 to 0.72. The charts were prepared for a helicopter having rotor blades with ideal twist. However, corrections may be applied to the hovering endurance to account for other combinations of twist and taper. The effects of stall and compressibility have been neglected.

From author's summary

825. Copp, M. R., and Fetner, Mary W., An analysis of airspeed, altitude, and acceleration data obtained from a twin-engine transport airplane operated over a feeder-line route in the Rocky mountains, *NACA TN* 3750, 23 pp., Oct. 1956.

Time-history data of airspeed, altitude, and acceleration obtained with the NACA VGH recorder from a twin-engine airplane operated by a regional feeder airline in the Rocky Mountains are evaluated to determine the magnitude and frequency of occurrence of gusts and gust accelerations and the operating airspeeds and altitudes. The results obtained are compared with the results previously obtained from a representative short-haul and long-haul operation.

The larger amount of turbulence at the low operating altitudes over the mountainous terrain resulted in a higher frequency of occurrence of gusts of small intensity for the feeder-line operation than for the other operations. The gusts of larger intensity were more frequent for the short-haul and long-haul operations. The differences in the gust-load factors for the operations appeared to be a direct reflection of the gust intensities in that the small load factors were more frequent for the feeder-line operation, whereas the larger values were less frequent than those for the short-haul and long-haul operations. From authors' summary

826. Cicala, P., and Miele, A., Generalized theory of the optimum thrust programming for the level flight of a rocket-powered aircraft, *Jet Propulsion* **26,** 6, 443–455, 473, June 1956.

Two theories are presented from the analysis of the optimum burning program for horizontal flight. The first theory is based on Green's theorem which leads to a simple straightforward proof of the necessary and sufficient conditions for the existence of a maximum. A linear relationship between thrust and engine mass is assumed. Hibbs' results are generalized by lifting any restriction concerning the shape of the drag polar and by considering a finite maximum burning rate for the engine. Two regions of best range are detected, one subsonic-transonic, the other one supersonic. The influence of the boundary conditions on the optimum technique of flight is discussed. A simple similarity rule for stratospheric solutions is pointed out.

The second theory, based on the variational method of Lagrange multipliers, considers the general case of an arbitrary one-to-one correspondence between thrust and propellant mass flow. Particular attention is devoted to the case of polygonal thrust characteristic. An example of application is worked out.

The concept of index value presented in a previous note is here emphasized. Such an index value appears to be a very effective device in controlling the composition of the optimum path for discontinuous Eulerian solutions. S. I. Cheng, USA

827. Cicala, P., Aerodynamics of flight (in Italian), *Atti Acad. naz. Lincei R. C. Sci. Fis. Mat. Nat.* (8) **20,** 5, 533–551, May 1955.

General equations are presented to analyze optimum paths of an aircraft in a vertical plane. The following hypotheses are used: The aircraft is a particle of variable mass; the acceleration of gravity is a constant; the aerodynamic lag is disregarded so that the drag is a function of altitude, velocity, and lift; the vector thrust is tangent to the flight path and its modulus is a function of altitude, velocity, and fuel consumed for unit time.

The variational problem is formulated as a problem of Mayer type. The system of Euler equations is derived accounting for the nonholonomic constraints due to the equations of motion and for the presence of additional constraints concerning the aircraft and the engine. A. Miele, USA

828. Pinkel, I. I., and Rosenberg, E. G., Seat design for crash worthiness, *NACA TN* 3777, 42 pp., Oct. 1956.

From a study of many crash-deceleration records, a simplified model of a crash-deceleration pulse is suggested which incorporates the essential properties of the pulse. The model pulse is considered to be made up of a base pulse on which are superimposed one or more secondary pulses of shorter duration. The results of a mathematical analysis of the seat-passenger deceleration in response to the airplane deceleration pulse are provided. On the basis of this information, presented as working charts, the maximum deceleration loads experienced by the seat and passenger in response to the airplane deceleration pulse can be computed. This maximum seat-passenger deceleration is found to depend on the natural frequency of the seat containing the passenger, considered as a mass-spring system.

Data are presented from full-scale laboratory and crash studies on the deceleration loads measured on dummy passengers in seats of standard and novel design. The general trends indicated by theory are obtained. From authors' summary

829. Martin, J., Ejection from high speed aircraft, *J. roy. aero. Soc.* **60,** 550, 659–668, Oct. 1956.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 779)

830. Williams, D., The theory and prevention of undamped aeroplane nosewheel shimmy, *Aero. Quart.* **7,** 3, 193–220, Aug. 1956.

A mathematical theory of nosewheel shimmy, without damping, is developed. Theory relies on an analysis based on fair length of castor and twin nosewheels, depending for legitimacy on suggested cure of increased length. Theory shows that shimmy can be eliminated by making castor length large enough, where castor length is governed by distance required for sideways-displaced tire to creep back to correct position in rolling forward. A table of the effects of various parts of the nosewheel system on shimmy is given. Some model experiments which support the conclusions reached

from the theory and a compact mechanism which gives large effective castor length are described.

A. F. W. Langford, Australia

831. Zartarian, G., Heller, A., and Ashley, H., Application of piston theory to certain elementary aeroelastic problems, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 163-181.

Lighthill's theory for unsteady airfoil motion at high Mach numbers is applied to elementary aeroelastic problems, particularly to the bending-torsion flutter of a typical section. The results are compared with those obtained by application of the supersonic flutter calculation methods of Garrick and Rubinow and are found to be satisfactory for most purposes if the Mach number is greater than about 2.5.

The authors conclude from their analysis that single-degree-of-freedom torsional instability is unlikely at very high speeds.

J. R. Spreiter, USA

832. Davidson, I. N., Some effects of mechanical damping on the self-induced aeroelastic oscillations of an axial compressor blade, *Aero. Quart.* **6,** 2, 81-98, May 1955.

For self-induced aeroelastic oscillations of an airfoil or blade the forcing gas bending moment is assumed in wave form expressed by a Fourier series. The viscous damping is bounded by a maximum value of logarithmic decrement of 1.3 and the Coulomb damping is approximated by a square wave series. An equation is given for an estimative approximation of the amplitude of a blade tip with both types of damping present.

In an illustrative example, exact solutions are given for various damping conditions and the results are compared with the approximate solution.

W. Ornstein, USA

833. Shen, S. F., Remarks on "An exact solution for two-dimensional linear panel flutter at supersonic speeds," *J. aero. Sci.* 22, 9, 656-657 (Readers' Forum), Sept. 1955.

834. Lambourne, N. C., Batson, A. S., and Chinneck, A., appendix by Garner, H. C., Rolling power measurements and comparative calculations for a flexible model wing constructed from Xylonite; *Aero. Res. Counc. Lond. Rep. Mem.* 2895, 35 pp., 1955.

Paper gives roll characteristics of aeroelastic wing from calculation and wind-tunnel test of a Xylonite (cellulose nitrate) model Thickness of Xylonite required for contour smoothness was found to make wing too stiff for low-speed testing. Comparison of test and calculated results shows fair agreement.

H. Luskin, USA

Propellers, Fans, Turbines, Pumps, etc.

(See Revs. 641, 726, 742, 752, 788, 832, 840, 841, 858, 859, 860, 861, 906)

Flow and Flight Test Techniques

(See also Revs. 784, 812, 813, 816, 903)

835. Ling, S. C., and Hubbard, P. G., The hot-film anemometer: a new device for fluid mechanics research, *J. aero. Sci.* **23,** 9, 890-891 (Readers' Forum), Sept. 1956.

The operation of the device is similar to that of a hot-wire anemometer. The sensing element consists of a very thin platinum film fused to a glass surface supporting the film. The device is suitable for measurements in flow of liquids and in supersonic or high-temperature flow of gases. In certain applications—e.g., in studies of boundary-layer transition where any disturbance due to the detecting instrument is to be avoided—a plane hot-film element can be mounted flush with a flow boundary. For applications in high-temperature flow, a film of rhodium fused on a quartz surface is claimed to be preferable because of the resistant properties of these materials at high temperatures.

Some electrical characteristics are given.

E. Petersohn, Sweden

836. Bomelburg, H. J., A method for the measurement of the flow of air by means of series of electric sparks, Inst. for fluid Dynamics and appl. Math., Univ. of Maryland, TN BN-68, 24 pp., 33 figs., Feb. 1955.

A technique has been developed in which series of electric sparks of low current are used to render visible the flow of air. Sparks traversing the air at very high frequency render visible successive displacement profiles; their photographic records furnish a large amount of detailed information. The method is applicable to both subsonic and supersonic flow.

The technique has been investigated in detail. Its merits and limitations are appraised as compared to other methods. Numerous photographs are presented to illustrate possible applications. Recommendations are made for the further improvement of the method.

From author's summary

837. Uberoi, M. S., Effect of wind-tunnel contraction on free-stream turbulence, *J. aero. Sci.* **23,** 8, 754-764, Aug. 1956.

Author describes experimental study of the changes in turbulent intensities and spectra through contractions as are employed in wind tunnels. Purpose of the study is to compare results with those predicted by the oversimplified linear theory which also neglects influences of viscosity. Experiments were conducted in air with contractions having area ratios of 4:1, 9:1, and 16:1. The magnitudes of the longitudinal turbulent intensities decrease while the lateral or cross-flow intensities increase as the flow is is contracted. Analysis of the data required subtraction of the turbulence induced by the tunnel fan which was assumed to be uncorrelated with the turbulence arising from vorticity. Agreement with theory is generally not good and some reasons are given for discrepancies. Detailed investigation shows that the lateral components which are of larger intensity, dissipate more energy through viscosity than through transfer to the longitudinal component (the smaller) the decay of which is, however, slightly more than compensated for by this small energy transfer, and hence slowly increases. Paper concludes with the observation that the general notion of turbulent motion leads one to expect local isotropy in the contraction whereas these present measurements show anisotropy. This apparent conflict is not resolved. An elementary treatment of turbulence decay in supersonic nozzles is included to show that increase in the mean speed and decrease in the mean speed and decrease in density both reduce turbulent intensities.

Paper is a valuable addition to experimental results of others which are summarized in extreme brevity.

J. P. Breslin, USA

838. Nordstrom, L.-E., Some preliminary results from wind tunnel measurements on models with annular wings at supersonic speeds, *Z. Flugwiss.* **4,** 8, 272-276, Aug. 1956.

839. Williams, J., Pankhurst, R. C., and Love, E. M., Wind-tunnel tests on the NPL 434 nose-slot suction aerofoil, *Aero. Res. Counc. Lond. Rep. Mem.* 2876, 10 pp., 1955.

Stalling tests were made on the 8% thick section NPL 434, which has been specially designed for nose-slot suction. At the higher suction quantities, the maximum lift of the airfoil was considerably greater than for the Lighthill and Glauert sections previously tested, when due allowance was made for the difference in camber. At low suction quantities, there was no improvement.

Tests with various slot widths showed that the velocity into the

slot as well as the suction quantity was important in relation to high maximum lift, and the the values of $C_{L_{max}}$ achieved with suction were determined more nearly uniquely by the momentum coefficient rather than by the quantity coefficient. Static pressure measurements made in the slot and ducting indicated that the suction head required at the stall was high, being at least equal to the dynamic head in the slot throat, but that some reduction could be expected from improvements in the slot entry shape.

From authors' summary

840. Edwards, G. G., Dickson, J. K., Sutton, F. B., and Demele, F. A., The results of wind-tunnel tests to a Mach number of 0.90 of a four-engine propeller-driven airplane configuration having a wing with 40° of sweepback and an aspect ratio of 10, *NACA TN* 3789, 171 pp., Sept. 1956.

A wind-tunnel investigation has been conducted to provide data for the study of the effects of operating propellers on the longitudinal characteristics of a four-engine tractor airplane configuration having a wing with 40° of sweepback and an aspect ratio of 10. A reflection-plane mounting was used and the semispan model represented the right-hand side of a complete hypothetical airplane. Single-rotation, right-hand propellers were operated at values of thrust coefficient ranging from 0 to 0.9 per propeller. The thrust was sufficient to simulate up to 5000 horsepower per engine at an altitude of 40,000 ft or up to 10,000 horsepower per engine at sea level, assuming the model to be 1/12 scale. The tests were conducted at Mach numbers from 0.082 to 0.90 and Reynolds numbers of 1,000,000 to 8,000,000. Variations in the model included several heights and incidences of the horizontal tail as well as tail removed, two arrangements of extended split flaps, several propeller-blade angles, and independent as well as simultaneous operation of the inboard and outboard propellers.

The coefficients of lift, longitudinal force, pitching moment, propeller thrust, and propeller power are presented in tabular form for various values of advance ratio at constant angles of attack. Selected portions of the data are presented in plotted form for various constant thrust coefficients.

From authors' summary by W. H. Phillips, USA

841. Edwards, G. G., Buell, D. A., Demele, F. A., and Sutton, F. B., Analysis of wind-tunnel tests to a Mach number of 0.90 of a four-engine propeller-driven airplane configuration having a wing with 40° of sweepback and an aspect ratio of 10, *NACA TN* 3790, 170 pp., Sept. 1956.

An investigation has been conducted at speeds up to a Mach number of 0.90 to determine the effects of operating propellers on the longitudinal characteristics of a four-engine tractor airplane configuration having a 40° swept wing with an aspect ratio of 10. Results of wind-tunnel tests of a model representing such an airplane configuration [see preceeding review] show that these effects are of most concern in the low-speed high-thrust flight regime. In the present report the low-speed data are analyzed to determine the source of the various effects and to indicate how the adverse effects can be reduced, and the high-speed data are discussed primarily from the standpoint of Mach number effects.

The analysis of the low-speed data indicates that the large variations of longitudinal stability with angle of attack resulted primarily from passage of the tail into and out of the slipstream. The slipstreams also created large lift increments on the wing, particularly with flaps deflected, which resulted in increases in stability (with increasing thrust coefficient) from the outboard propeller and decreases in stability from the inboard propeller. It was concluded that the longitudinal stability characteristics of the model could be improved by moving the nacelles outward, increasing the tail height, and reducing the tail span. Estimates of the stability with nacelles moved 0.1 of the semispan outboard of their original position are shown, along with estimates of rolling and yawing moments resulting from loss of thrust on an outboard engine.

A study of the high-speed data indicates that the effects of operating propellers on the longitudinal characteristics of the model were comparatively small at high subsonic speeds.

The propulsive characteristics of the model are presented and compared with those of the isolated propeller for both low-speed and high-speed conditions of operation.

From authors' summary by W. H. Phillips, USA

842. Seiff, A., A free-flight wind tunnel for aerodynamic testing at hypersonic speeds, *NACA Rep.* 1222, 17 pp., 1955.

The supersonic free-flight wind tunnel is a facility at the Ames Laboratory of the NACA in which aerodynamic test models are gun-launched at high speed and directed upstream through the test section of a supersonic wind tunnel. In this way, test Mach numbers up to 10 have been attained and indications are that still higher speeds will be realized. An advantage of this technique is that the air and model temperatures simulate those of flight through the atmosphere. Also the Reynolds numbers are high. Aerodynamic measurements are made from photographic observation of the model flight. Instruments and techniques have been developed for measuring the following aerodynamic properties: drag, initial lift-curve slope, initial pitching-moment-curve slope, center of pressure, skin friction, boundary-layer transition, damping in roll, and aileron effectiveness.

From author's summary

843. Morelli, P., Wind-tunnel tests on a new type of aerodynamic brake for gliders (in Italian), *Aerotecnica* **35,** 1, 17–21, Feb. 1955.

The brakes consist of two plates that are adherent to the fuselage sides and can be rotated through an angle of 90°. The polar and moment curves and the results of the wake survey are reported.

The experiments show that the brakes, when perpendicular to the stream direction, cause an interference on the wing, which in turn increases the brake efficiency.

From author's summary

844. Howland, W. L., and Buzzetti, C. J., Flight load measurements and analysis, *SAE Trans.* **63,** 471–480, 1955.

Knowledge of loads on major structural parts of an airplane while in flight is needed for complete utilization of the airplane's strength and capabilities. Some in-flight measuring techniques and equipment for reducing the data thus obtained are discussed in this paper.

Instrumentation and calibration of strain gages for measuring in-flight air loads are described in detail. Wing bending-moment measurements obtained on a Navy PV-2 airplane are used to illustrate data-reduction procedure.

From authors' summary

845. Lewandowski, R., Flight altitude, its aspects, measurements and reduction methods (in Polish), *Technika Lotnicza* **10,** 2, 44–52, Mar.-Apr. 1955.

This description of characteristic aspects of measurement of the altitude of flight is based on American, Russian, and German books and papers.

M. Z. Krzywoblocki, USA

846. Bromberg, R., Use of the shock tube wall boundary layer in heat transfer studies, *Jet Propulsion* **26,** 9, 737–744, 756, Sept. 1956.

Paper is concerned with the heat transfer in a laminar boundary layer formed behind a shock wave advancing into stationary fluid bounded by a solid wall. Using the boundary-layer equations in the form derived by Crocco, it is deduced that, upon passage of the shock, the wall temperature instantaneously rises to a new equilibrium value and then remains constant. This result is subject to the following assumptions: (1) for the short times involved in the motion of the shock wave (as for example in a shock tube), the wall behaves, with respect to heat conduction, like a slab of semi-infinite thickness; (2) the gas properties behind the shock are not

affected by complex phenomena such as dissociation and recombination. This simple wall temperature response stems from the fact that the wall heat flux varies inversely as the square root of the distance from the shock. For a shock moving at constant velocity, the wall heat flux at a fixed position on the wall will then vary inversely as the square root of time, which is the time dependence required to instantaneously raise a semi-infinite slab to uniform surface temperature.

Author concludes that, due to the simple wall temperature response, the shock tube can be used to study the character of the boundary layer at high temperatures, as deviations from the simple response (after correction is made for the thermal capacity of the wall temperature measuring element as indicated in the paper) will give an indication of the complex phenomena occuring in the gas.

R. Siegel, USA

847. Fay, J. A., and Lekawa, E., Ignition of combustible gases by converging shock waves, *J. appl. Phys.* **27**, 3, 261–266, Mar. 1956.

H_2–O_2 and H_2–air mixtures were ignited in the Perry-Kantrovitz apparatus [AMR **5**, Rev. 176]. The minimum shock Mach numbers needed to produce ignition at 1 atm pressure were in all cases in the range 1.065 to 1.306. Ignition energies per cm of axial length for spark and for converging cylindrical shock wave-ignitions were found to be comparable; the former were calculated by dividing the minimum ignition energy by the quenching distance and the latter from the theoretical temperature distribution remaining after the converging shock wave had reflected, summing only over a cylinder of diameter equal to the quenching distance. An analysis of the unsteady heat-conduction problem lends support to the choice of the quenching distance as the significant dimension of the region over which heat addition is effective in causing ignition.

In reviewer's opinion, this is a valuable paper from the scientific viewpoint and also from the engineering viewpoint since it shows that shock-tube design can reasonably be based on the relatively easily obtained spark ignition energies and quenching distances for the gas mixtures to be studied.

B. P. Mullins, England

The following ten papers, (Revs. 848–857) were presented at the Fifth Meeting of the Wind Tunnel and Model Testing Panel, AGARD Publication AG/5/P6.

This volume contains 10 papers by authors of various AGARD nations dealing mainly with wind-tunnel technique, design and operation. Commenting on the collection as a whole, reviewer finds a curious lack of continuity between the papers, and considerable repetition of material. Indeed some of the papers seem to consist of no more than a few debatable generalizations drawn from very limited experience. Several of the papers, however, are excellent, and present complete and reliable data. All papers will be reviewed in the order of appearance in the published volume.

848. van de Vooren, A. I., Measurements of aerodynamic forces on oscillating aerofoils, pp. 7–13.

In this paper author presents some experimental verification of two-dimensional theoretical linearized predictions of the aerodynamic forces and moments acting on an oscillatory airfoil in low-speed flow. Three assumptions are considered to require checking; these are the assumption of a linear relation between aerodynamic forces and the motion, the assumption that Reynolds number effects are negligible, and the question of the theoretical dependency of the coefficients on the basic reduced frequency parameter. The experimental technique used is that of forcing a rigid model by a spring, and measuring the response to a harmonic oscillation. In these tests a two-dimensional airfoil was used. It was found that under certain conditions, notably when the axis of rotation coincides with the quarter chord axis, the linearity assumption was not satisfied; it was further observed that the nonlinearity was most pronounced near the critical Reynolds number. The author notes that the transition point is a function of angle of attack, and, since the transition points move on the top and bottom as the airfoil changes attitude, the camber will be effectively changed and an additional periodic aerodynamic moment, not linear with amplitude, introduced. This could be avoided by insuring that the boundary layer is completely turbulent by introduction of tripping wires. The author achieved such an effect experimentally, at the same time making negligible any variation with Reynolds number. The experimental measurements were found to be in satisfactory agreement generally with theory.

G. V. Bull, Canada

849. Valensi, J., A review of the techniques of measuring oscillatory aerodynamic forces and moments on models oscillating in wind tunnels in use on the Continent, pp. 14–49.

Author reviews the basic principles of the three main techniques which are used in determining oscillatory aerodynamic characteristics, i.e., the method of decaying oscillations, the method of forcing through a spring, and the method of inexorable forcing. The discussions refer primarily to subsonic studies. In the second part of his paper, author reviews the equations of motion for perturbed flight. The remainder of the report describes the methods and apparatus in the various laboratories of Europe. A summary table of methods and equipment against laboratories and models is presented as appendix 3.

This report is an excellent survey of this field and should be of great interest to the wind-tunnel operator. The paper could stand editing.

G. V. Bull, Canada

850. Timman, R., Report on methods and results of nonstationary airfoil theory, pp. 50–55.

This paper reviews the theoretical approaches to the problem of nonstationary airfoil theory, where nonstationary boundary-layer effects are ignored. The mathematical problem is formulated and applied to two-dimensional flow of (1) an incompressible fluid, (2) a subsonic compressible fluid, and (3) a supersonic fluid. A brief discussion of the application to three-dimensional flow is given. An extensive bibliography (65 references) is given.

G. V. Bull, Canada

851. Shortal, J. A., Techniques of model testing in free flight, pp. 56–68.

This paper consists of a descriptive review of the NACA free-flight facility at Wallops Island. Reviewer was surprised to note the absence of any discussion on the accuracy and reliability of the technique, and on reduction methods. Further, the presentation surprisingly fails to mention any instrument problems, and in general presents too much of an over-simplified picture. Reviewer is amazed at the use of the helium gun for the sabot-launching of scale models, since an ordinary smooth-bored gun can be used far more economically and with much greater flexibility (this technique is used in Canada to launch models as large as 6 inches in diameter up to Mach numbers as high as 4.5 and is being developed to launch 12-in. diameter models up to Mach 3).

G. V. Bull, Canada

852. Greatrex, F. B., Jet-engine-driven wind tunnels, pp. 69–83.

Author describes several jet-engine-driven wind-tunnel

facilities in the United Kingdom; these tunnels are generally restricted to subsonic and transonic testing, although author points out they are capable of use in the low-supersonic speed range. Some of the advantages of the jet-engine-driven tunnel are discussed, and the number of facilities of this type in use in Europe are listed.

G. V. Bull, Canada

853. Markham, J., Some aspects of supersonic wind tunnel operating techniques, pp. 84–97.

This paper describes primarily the wind-tunnel facility of the Naval Supersonic Laboratory of the Massachusetts Institute of Technology. The generalization implied by the title is debatable. G. V. Bull, Canada

854. Lukasiewicz, J., Development of intermittent wind tunnel technique, pp. 98–126.

This paper is an excellent presentation of the subject and does not suffer, as do most of the other papers in this volume, by the author shying away from thermodynamic considerations, expressed in mathematical language. After a general discussion of the history of supersonic tunnels, author discusses briefly intermittent and continuous type supersonic wind tunnels. Thermodynamic considerations are used to express the starting and operating pressure ratios, time of run, and heating requirements for intermittent tunnels of the pressure-driven and vacuum-driven types. Experimental results are quoted from the NAE 30-in. wind tunnel. A comparison study is presented between a 4-ft square pressure-driven tunnel and a 6-ft square vacuum-operated tunnel; it is concluded that the pressure-driven tunnel is economically and aerodynamically superior to the vacuum tunnel.

Author describes a balance under development at NAE to drive a model through a range of incidences during each tunnel run (of approximately 15 sec). The relative merits of intermittent and continuous tunnels are discussed, and the author suggests that perhaps an ideal arrangement is a large intermittent tunnel with a smaller continuous one running off the same power supply.

G. V. Bull, Canada

855. Huntsberger, R. F., and Parsons, J. F., The design of large high-speed wind tunnels, pp. 127–152.

This paper reviews the Unitary Facility of the NACA Ames Aeronautical Laboratory and presents somewhat of a composite picture of NACA experience on large high-speed wind tunnels. The paper does not present any of the analyses leading to the general conclusions, and hence these conclusions would be difficult to debate. On the other hand, many of the remarks are made in light of experience and hence are of considerable interest.

Authors discuss some general problems associated with large wind-tunnel design. Considering the question of nozzles, authors state that, in general, it will be found uneconomical to build high-speed wind tunnels in large sizes with fixed nozzle blocks. References are quoted for detailed nozzle design methods, and an interesting practice of the NACA of making scale models of the larger nozzle blocks for testing purposes is described. Some limits on accuracy are quoted in terms of flow deviations; the authors consider flow deviations of $\pm 0.10^{\circ}$ to be the practical limit of accuracy. Some nozzles in use are described, as well as the methods of making them; of particular interest is the discussion of surface finish. Diffusers for use in these larger tunnels are discussed, and the problem of diffuser design for transonic wind tunnels, complicated by the model support, presented. Considerations of subsonic air passages and compressor selection are made, and compressor design discussed. Power and structural considerations are presented. The authors certainly achieve their purpose of emphasizing some of the problems associated with large high-speed wind-tunnel designs, and the compromises necessary.

G. V. Bull, Canada

856. Wadkin, W., and Barnes, T., Notes on the design and construction of the welded steel structure for the 8 ft × 8 ft high speed wind tunnel at the National Aeronautical Establishment, Bedford, pp. 153–166.

This paper reviews the design criteria and techniques used in the welded steel structure of the tunnel described in the title, as well as stating the progress of the work. In respect to preceding papers, nothing essentially new or novel is presented, although the inclusion of more details of the design may be of interest.

G. V. Bull, Canada

857. Clark, J., Design and construction aspects of high power wind tunnel drive systems and large diameter compressors, pp. 167–192.

Author reviews various drive requirements, and compressor and drive arrangements. Some of the major problems encountered in design of large wind-tunnel drive systems such as whipping speed, torsional vibration, shaft alignment, and dynamic balance are discussed. The mechanical design and constructional aspects of large-diameter wind-tunnel compressors are discussed by comparing various types of rotor structure and considering some of the major problems encountered in mechanical design of large wind-tunnel compressors, such as stress, stress in the rotor blades, stress in compressor rotor blades, stress in compressor rotor disks, and vibration. Many interesting design data are presented.

G. V. Bull, Canada

Thermodynamics

(See also Revs. 733, 734, 736, 743, 790, 803, 811, 877, 898, 899, 900, 901, 903, 907, 929, 940)

858. Baumann, H., The open-cycle gas turbine in connection with blast furnaces in steelworks, *Brown Boveri Rev.* **43,** 3/4, 79–91, Mar./Apr. 1956.

To improve efficiency of blast generation in furnaces for steelworks, author proposes use of exhaust from open-cycle gas turbine as combustion air for air heater and for preheating the blast-furnace gas. Formulas are developed, and two examples are given to illustrate possible improvements which must be balanced against some limitations in operation. F. G. Blight, Australia

859. Hawthorne, W. R., The thermodynamics of cooled turbines. Part I. The turbine stage, *Trans. ASME* **78,** 8, 1765–1779, Nov. 1956.

860. Hawthorne, W. R., The thermodynamics of cooled turbines. Part 2. The multistage turbine, *Trans. ASME* **78,** 8, 1781–1786, Nov. 1956.

861. Sanders, K. L., Approximative determination of the ceiling of turbojet engines, *J. aero. Sci.* **23,** 8, p. 804 (Readers' Forum), Aug. 1956.

862. Kuljian, H. A., and Fadden, W. J., Jr., A new way to simplify the steam power plant, ASME Semiann. Meet., Cleveland, O., June 1956. Pap. 56-SA-34, 7 pp.

Purpose of this paper is to present a new approach to the ever-urgent problem of simplifying the installation and operation of steam power plants. Two alternative methods are involved, both of which combine regenerative feedwater heaters in a singel shell. One integrates the closed-type heat exchangers; the other employs a new method of using open-type heat exchangers with intermediate locks. By either method, authors conclude that a saving in initial investment of from $10.00 to $15.00 per kilowatt will be obtained.

From authors' summary

863. Komedera, M., The domestic heat pump, *Engineering* **182,** 4720, 236–240, Aug. 1956.

864. Schokker, J. C. A., Approximate determination of horse-power, *Inter. Shipbldg. Progr.* **3,** 23, 383–384, July 1956.

865. Jarre, G., Principles of gas dynamics of mixtures. Parts I, II (in Italian), *Aerotecnica* **35,** 3, 137–143, June 1955; **35,** 4, 186–194, Aug. 1955.

866. Bozza, G., Diffusion and flow of two gases in a porous media (in Italian), *Termotecnica* **8,** 3, 129–136, 1954.

867. Benzler, H., Equation of state of pure fluids with special regard to supercritical pressure (in German), *Forsch. Geb. Ing.-Wes.* 21, 3, p. 97, 1955.

868. Brun, R. J., Lewis, W., Perkins, P. J., and Serafini, J. S., Impingement of cloud droplets on a cylinder and procedure for measuring liquid-water content and droplet sizes in supercooled clouds by rotating multicylinder method, *NACA Rep.* 1215, 43 pp., 1955.

869. Pattison, J. R., and Lonsdale, T. H., The enthalpy of a 0.12% carbon steel, *J. Iron Steel Inst. Lond.* **183,** part 3, 284–286, July 1956.

A 0.12%-carbon, 0.44%-manganese steel has been investigated by water calorimetry over the temperature range of 1000-1630C. From the enthalpy data obtained, values have been assigned to the heats of transformation at the γ to $\delta + \gamma$ phase change temperature (1467 C), the peritectic temperature (1481 C), and the liquidus temperature (1509 C). The mean specific heat was found to be 0.157 in the austenite phase compared to 0.161 for pure iron, and 0.146 in the liquidus compared to 0.144 for pure iron.

From authors' summary

870. Moore, A. E., The thermal properties of composite concrete floors, *Mag. Concr. Res.* **6,** 18, 133–138, Dec. 1954.

871. Savornin, J., and Lejeune, G., Improvement of solar distillation apparati (in French), *C. R. Acad. Sci. Paris* **243,** 1, 32–34, July 1956.

The aim of this study was to improve the design of solar stills converting salt water into fresh. Glass-enclosed roof-shaped structures were used, following previous models. No improvements could be obtained by extending the area of condensing surfaces, or by distributing sea water in small troughs. A flat tilted model produced 38% greater water yields than the roof-type still, in good agreement with results described by Maria Telkes in "Proceedings, World symposium on applied solar energy," Phoenix, 1956, p. 73.

M. Telkes, USA

Heat and Mass Transfer

(See also Revs. 659, 660, 662, 691, 770, 798, 808, 809, 810, 811, 812, 815, 846, 862, 863, 871, 903, 905, 908, 915)

872. Douglas, J., Jr., On the errors in analogue solutions of heat conduction problems, *Quart. appl. Math.* **14,** 3, 333–335 (Notes), Oct. 1956.

Paper considers constant diffusivity heat-conduction equation. Replace space derivatives by their finite difference equivalents, but retain derivatives in time variable. As is well known, this yields a system of ordinary differential equations. Hartree has conjectured that error is $0(\Delta x^2)$ where Δx is largest space increment. Here conjecture is proved. Y. L. Luke, USA

873. Lessen, M., Note on the symmetrical property of the thermal conductivity tensor, *Quart. appl. Math.* **14,** 2, 208–209 (Notes), July 1956.

874. Chao, C. C., and Weiner, J. H., Heat conduction in semi-infinite solid in contact with linearly increasing mass of fluid, *Quart. appl. Math.* **14,** 2, 214–217 (Notes), July 1956.

Liquid, of temperature V, is poured at uniform rate (m lbs/sq in.) on a semi-infinite solid ($x \geqslant 0$) originally at temperature $u = 0$. Authors assume that the liquid is so thoroughly stirred that it may be regarded as being at the solid interface temperature $u(0, t)$. Authors then calculate the variation of $u(0, t)$ with t. Clearly this increases from 0 asymptotically toward V. In practice, the fluid temperature $v(x, t)$ $(x \leqslant 0)$ is between V and $u(0, t)$, and therefore solution obtained constitutes a lower bound for the fluid temperature. G. Horvay, USA

875. Jaeger, J. C., Conduction of heat in an infinite region bounded internally by a circular cylinder of a perfect conductor, *Austr. J. Phys.* **9,** 2, 167–179, June 1956.

Theoretical consideration is given to the radial flow of heat in an infinite region bounded internally by a circular cylinder of radius a containing a perfect conductor. A contact resistance between the cylinder and the infinite region is postulated. Among the problems considered are (1) the perfect conductor and the infinite region initially at different temperatures and (2) various forms of heat supply to the perfect conductor. Numerical results in terms of dimensionless parameters are presented. Various physical situations which approximate the theoretical problem are considered.

L. Lapidus, USA

876. Jain, S. C., and Krishnan, K. S., The distribution of temperature along a thin rod electrically heated in vacuo. VI. End-losses, *Proc. roy. Soc. Lond. (A)* **229,** 439–445, May 1955.

In their previous papers the authors have computed the distribution along the filament of temperature, resistance, heat generated, radiation, brightness, evaporation rate, thermionic emission, etc. Now they find corrections for end losses which give, for each of these properties, the equivalent length of a filament without conduction losses at the ends. H. D. Block, USA

877. Hsu, S.-T., Determination of thermal properties of metals with the aid of unsteady heat-flow procedure and avoiding calorimetric measurement (in German), *Mitt. Inst. Thermodyn. Verbrennungsmotor.* no. 14, 87 pp., 1954; *ETH, Zurich* Prom. no. 2324.

878. Destable, P., Contribution to the study of temperature distributions and heat losses in soil under steady-state conditions (in French), *C. R. Acad. Sci. Paris* **243,** 1, 28–30, July 1956.

Paper states that the temperature distribution in the plane of contact between a wall and the soil can be expressed in terms of the temperatures measured at the four vertexes of the rectangular

base. The rate of heat flow to soil through base is independent of this distribution and can be expressed in terms of the mean value of the flow temperatures at the vertexes and other data in the problem.

There being no proofs given, reviewer finds it impossible to check on the correctness of the results. J. Kestin, USA

879. Destable, P., Contribution to the study of heat transfer between the soil and walls in thermal installations and dwellings under nonsteady-state conditions (in French), *C. R. Acad. Sci. Paris* **242,** 26, 3047–3050, June 1956.

Paper is concerned with a solution of the general Fourier equation which has the prescribed form

$$\Theta(x,y,z,t) = \varphi(x,t)\,\Phi\,(y,t)\,\psi(z,t)$$

$\varphi(x,t)$ and $\Phi\,(y,t)$ denoting the temperature distribution in the tow planes of symmetry of a slab of width $2l$ in x-direction and $2l'$ in y-direction. Expressions for the rate of heat transfer through the base and for the function $\varphi(x,t)$ are given.

The note is sketchy and does not give results which can be applied to the solution of practical problems.

J. Kestin, USA

880. Vallet, P., Progress in the solidification of prismatic or cylindrical ingots in a mold (in French), *C. R. Acad. Sci. Paris* **242,** 19, 2305–2308, May 1956. **Vallet, P., Progress in the solidification of polyhedric or spherical ingots** (in French), *ibid.* **242,** 20, 2448–2451, May 1956.

Author gives approximate treatment of the problem of melt solidifying in ingot moulds of cylindrical, prismatic, polyhedric, and spherical shapes by assuming that, instead of the *thickness* of the material solidified [compare Lightfoot's assumption, *J. Iron Steel Inst.* **119,** p. 364, 1929], it is the *volume* solidified that would be proportional to the square root of time elapsed after pourings. This assumption is shown to lead to approximate equations that satisfactorily represent experimental data obtained by others.

H. Blok, Holland

881. Selig, F., Notes on the problem of Stefan (in German), *Öst. Ing.-Arch.* **10,** 2/3, 277–280, 1956.

Author solves the following problem: A semi-infinite ice prisma, lying in the positive x-axis, isolated on the mantle and with initial temperature zero, gets at the time $t = 0$ into contact with a medium of temperature $T > 0$. To be determined is the moving boundary $x_1(t)$ between the ice and the spreading water layer. This problem was solved by Stefan for the case T = const. Author solves it for the case of a time-variable temperature $T(0;t) = \varphi(t)$. The temperature $T(x,t)$ in the water layer has to satisfy the heat conduction equation $T_t = a^2 T_{xx}$ with boundary conditions $T(0;t) = \varphi(t)$, $T(x_1(t), t) = 0$ and with the corresponding transfer condition on $x_1(t)$. Author comes—by help of a special heat-sources layer—to an integrodifferential equation for the unknown function $x_1(t)$. As its special case for $\varphi(t)$ = const, he gets the known Stefan's result. Author presents also a method for approximative solution of the equation.

In the conclusion, author notes that, for the case when $x_1(t)$ is known, the equation turns into Volterra's integral equation for the unknown boundary temperature $\varphi(t)$. He shows how the equation can then be approximatively solved.

K. Rektorys, Czechoslovakia

882. Paschkis, V., and Stolz, G., Jr., Quenching as a heat transfer problem, *J. Metals* **8,** 8, 1074–1075, Aug. 1956.

Boundary conductance—the heat transfer from the surface of a quenched object to the quenchant—largely defines harness resulting from quenching, according to this first report on a cooperative project carried out in the Heat and Mass Flow Analyzer Laboratory at Columbia University.

During the quench, temperatures are measured within the sample as continuous functions of time. Curves are extrapolated to surface conditions by the Heat and Mass Flow Analyzer, and the rate of heat flow from the surface may also be computed. The surface temperature and the heat flux in turn give the boundary conductance.

Use of silver samples, advantageous from an experimental viewpoint, is permissible since the boundary conductance is assumed to be independent of the material. Silver-nickel thermocouples in sample give the temperature pattern. Pure nickel wires, 0.020-in. diam and insulated by alundum tubing, are welded to the bottom of 0.042-in. diam holes by discharge of electric capacitors, and the nickel wires are brought out through the supporting neck. The sample is the other leg of the thermocouple with a 0.065-in. silver wire from the sample as the common thermocouple return.

The neck is fastened to a coaxial inconel tube, which extends through a carbon gland of a vertical tubular electric furnace. The inconel tube is fastened to the dropping mechanism. A quench tank with viewing windows is under the furnace.

The furnace is closed while the sample is heated and a nitrogen blanket is maintained. To quench, the bottom plug is removed and the sample drops into the quench bath at a known and adjustable speed. During a quench, thermocouple emf-time curves are recorded with five of the six oscillograph channels, and one channel records sample position during the drop.

From authors' summary

883. Oakes, G., A simple method for computing the temperature history of a body entering the atmosphere at high supersonic velocities, *Jet Propulsion* **26,** 10 (part 1), 888–891 (Technical notes), Oct. 1956.

Author describes a method for predicting the transient temperature change of a high-speed projectile reentering the atmosphere. After setting out the differential equations governing the motion and heat transfer, while making a number of simplifying assumptions, a numerical method using finite difference equations and successive approximations is presented for predicting the temperature-altitude relation for the projectile skin.

The numerical procedure, though lengthy, can be carried out with an IBM 701 digital computer, but the computer is described in another paper. There are misprints in equations [6] and (8).

Y. R. Mayhew, England

884. Ehricke, K. A., Aero-thermodynamics of descending orbital vehicles, *Astronaut. Acta* **2,** 1, 1–19, 1956.

Author summarizes flat plate compressible boundary-layer theories of laminar and turbulent heat transfer utilizing reference temperature method, for use in calculating the heat transfer on descending orbital vehicles. Approximate computations of Reynolds number variation, and the method for determining dissociated gas properties, across oblique and normal shock waves are given as a function of flight velocity.

Main criticism would seem to be that these heat-transfer theories are not substantiated for a dissociating and ionizing gas with finite recombination rates where thermochemical equilibrium is not necessarily achieved. Furthermore, theories do not consider diffusion of atoms and ions, which may recombine at wall with appreciable increase in heat-transfer rate. Since, for flight speeds being considered, some sort of blunt nose is mandatory, it would seem main consideration must be given to stagnation-point heat-transfer rates where heat transfer is highest, although this point was not considered. Complete solutions of this problem are now available [Fay & Riddell, AVCO Research Lab R.N. 18, Everett, Mass., June 1956], while with these solutions laminar heat transfer around body can be simply computed by method of Lees [AMR **9,** Rev. 3390]. Also, if deceleration occurs at high altitudes, as is likely, question of turbulent flow may be academic. Important problems of gaseous and surface radiation are not considered.

R. F. Probstein, USA

885. Covert, E., and Durgin, F., A note on transient aerodynamic heating, *J. aero. Sci.* **23,** 7, 699–700 (Readers' Forum), July 1956.

Purpose of present note is to outline in very brief fashion a general method of calculating solutions to the problem of heat transfer through a laminar boundary layer with arbitrary surface temperature distribution. Method is not restricted to thin-skinned bodies; however, properties of the material are assumed constant. As a particular case, the temperature response of a hemisphere subjected to step function in velocity has been calculated. Surface temperature-time measurements at two angular positions on the hemisphere, one being the stagnation point, in a $M = 3.01$ airstream are in good agreement with an asymptotic solution for large time. A. Ritter, USA

886. Leadon, B. M., and Scott, C. J., Transpiration cooling experiments in a turbulent boundary layer at M = 3, *J. aero. Sci.* **23,** 8, 798–799 (Readers' Forum), Aug. 1956.

Turbulent recovery factor and heat-transfer measurements have been made on a porous flat wall section at a nominal Mach number of 3.0 and a Reynolds number of approximately 4×10^6, using both air and helium as the transpired gas. Measured heat-transfer coefficients correlate well with the compressible theory of Rubesin [AMR **8,** Rev. 2139] for air and qualitatively with simple film theory [AMR **8,** Rev. 245; also earlier paper by present authors] for either coolant, indicating that the heat transfer from a turbulent boundary layer can be reduced by transpiration cooling to well below that of the uncooled boundary layer at the same Reynolds number. From authors' summary

887. Collis, D. C., Forced convection of heat from cylinders at low Reynolds numbers, *J. aero. Sci.* **23,** 7, 697–698, (Readers' Forum), July 1956.

An investigation of forced-convection heat transfer to an air stream of low turbulence level has been carried out on cylindrical wires ranging from 0.00012 to 0.0021 in. in diameter for temperature differences from 30 to 320 C and air speeds normal to the wire of up to 240 fps. This range of variables is of particular interest in hot-wire anemometry. From author's summary

888. Probstein, R. F., Methods of calculating the equilibrium laminar heat transfer rate at hypersonic flight speeds, *Jet Propulsion* **26,** 6, 497–499 (Technical Notes), June 1956.

This note presents an approximate method of computation of the heat-transfer rate for laminar boundary layers on blunt-nosed bodies at hypersonic flight speeds for the case of thermodynamic equilibrium, wherein the rates of dissociation and combination are assumed to be very fast in comparison with the rates of convection and diffusion. Approximations are introduced which uncouple the energy and momentum equations so that the energy equation may be solved independently, using essentially the velocity profiles from the simpler case of constant gas properties across the boundary layer. An iteration scheme is used to solve the resulting nonlinear integral equation.

This approximate method is illustrated by means of sample calculations for flow at the stagnation point for a free-stream velocity of 18,700 ft/sec and a wall temperature of 1,000 R. The calculated results are found to agree well with the approximate solution given by Lees and the "exact" solutions of Cohen and Reshotko, and of Mark. J. Kaye, USA

889. Yuge, T., Theory of distributions of the coefficients of heat transfer of spheres, *Rep. Inst. high Speed Mech., Tohôku Univ. (B)* no. 6, 115–141, 1956.

The local Nusselt modulus has been calculated for the incompressible laminar boundary layer over a sphere placed in a uniform velocity field. The calculations were made by two methods, termed approximate and exact; the approximated method was found to give values of the Nusselt modulus which were 20% greater than those given by the exact method. In addition, the calculations were performed using the velocity distribution from potential flow. The potential flow solution gave values of Nusselt modulus greatly in excess of the other two. D. C. Hamilton, USA

890. Kuznetsov, N. V., et al, Optimum velocity of air and flue gases in air preheaters and a technical-economic comparison of heating surfaces (in Russian), *Teploenergetika* no. 9, 18–21, 1955.

This is the second part of a research paper prepared by same authors.

The presence of air and flue gases in an air preheater, with a corresponding heat release, brings out that the area of the relative capacity depends upon two variables, air and gas velocities.

The most advantageous ratio of air to flue gas velocities is 0.5 for tubular, 0.95 for laminated, 1.05 for C.I. with finned surface, and 0.7 for tooth-formed preheaters.

The most favorable flue gas velocity in an air preheater does not depend upon power costs for induced fan drives. Setting a price of 5.5 and 11 Russian cents per kwh for the same group of preheaters, with an 80% load and 100 C temperature difference gave velocity differences ranging from 1.5 m/sec for C.I. tooth-finned preheaters to 0.7 m/sec for tubular type. Higher velocities are for higher energy cost.

As the over-all volume of C.I. preheaters is not given, this comparison is, in the opinion of this reviewer, somewhat misleading, unless the first article supplied the missing data.

As for the technical-economical comparison of the same group of preheaters, authors used the same method of calculations (not given here) as for boiler economizers and 100 C temperature difference. Applying the most favorable air velocities for gas and air gave the following results: A tubular preheater for a given heating surface is 1/2 the volume of a laminated one, uses 2.3 times less metal, costs 25% less, and uses 40% less power for induced fan drives. C.I. preheaters with tooth-shaped fins are still less economical, as they take 30% more volume, 38% heavier, require 43% more power, and cost 25% more. Such preheaters price themselves out of the market. Their use is justified only in installations where fuels with a sulphur content are burned, to withstand the corrosive action of sulphurous gases given off by products of combustion.

Of the two C.I.-type preheaters, the one with tooth-finned surfaces has 30% less volume, 30% less weight, and is 25% cheaper. Its drawback is, even with most favorable velocities, power consumption, which is 50% higher, hence higher velocities.

W. Green, USA

891. Dwyer, O. E., Sheehan, T. V., Weisman, J., Horn, F. L., and Schomer, R. T., Cross flow of water through a tube bank at Reynolds numbers up to a million, *Indust. Engng. Chem.* **48,** 10, 1836–1846, Oct. 1956.

Authors present experimental heat-transfer coefficients and pressure drops of water cross-flowing through a staggered tube bank, 10 rows wide and 20 deep for a Reynolds number varying from 200,000 to 1,200,000. This is of great importance to designers of heat-exchanger systems in nuclear power plants. The effect of nonboiling, transition, and fullboiling regions on the heat transfer is discussed.

Method consisted of using a closed circulatory water system pumping 6000 gal/min at 360 F, in a pressure range of 380–410 lb/sq in. where Prandtl number was 0.93 to 0.97 and linear velocity range of V_{max} was 0.8 to 31 ft/sec. Tube bank consisted of 200 elements, either nickel tubes or solid carbon-steel rods, 0.810-in. O.D. The 0.063-in.-wall nickel tubes were heated electrically (d-c) by their own resistance.

It was concluded that the data were represented best by $\overline{b} = 0.19 (Re)^{0.8}$, which showed an average tube coefficient ($\overline{b}$) was 60% greater than that obtained by extrapolation of the Colburn equation

to Reynolds number (Re) of 1,000,000. Superheat to initiate boiling was about 25 F, but did not vary with Reynolds number. Pressure drop results agreed with those of Jakob's relation which were obtained on air at much lower Reynolds number. Reviewer believes that, even though the work was directed in a limited direction, the scale of the experimental setup was large enough to extrapolate to prototype heat exchangers. H. Majors, Jr., USA

892. Hoff, N. J., Comparison of radiant and conductive heat transfer in a supersonic wing, *J. aero. Sci.* **23,** 7, 694-696 (Readers' Forum), July 1956.

Author makes an attempt to estimate the order of magnitude of the ratio of radiant to conductive heat transfer, by splitting up the whole process into two separated processes; one consisting of pure radiation and one consisting of pure conduction. Average temperatures are derived starting from the same initial conditions and after the same time. Temperatures thus found are compared with each other, for they are a measure for the heat transferred. The conclusion of the author about the ratios thus found may be slightly changed when another approximation is used in calculating the conduction process.

Whereas author uses as an approximation the heat-transfer process that occurs in a slab of infinite thickness the surface of which is suddenly brought to and held at some temperature, a better approximation may be had by considering the same sort of process that occurs in a slab of finite thickness, both surfaces of which are suddenly brought to and held at some temperature.

Especially in the first minute after the start of the process the average temperatures obtained in both processes differ considerably.

No indication is given how near the real process of simultaneous radiant and conductive heat transfer is approximated.

J. H. van de Stadt, Holland

893. Oppenheim, A.K., The engineering radiation problem—an example of the interaction between engineering and mathematics, *ZAMM* **36,** 3/4, 81-93, Mar./Apr. 1956.

A brief but complete summary of the methods of analysis of radiant heat-transfer problems is given. The methods are classified as: accounting method, calculus method, and network method. From the point of view of the engineer concerned with geometrically complex systems, author shows the network method to be more suitable for numerical calculation than the calculus method, since in such cases one is interested in discerning the effects of individual components of the system. A. J. Chapman, USA

894. Sleicher, C. A., Jr., and Churchill, S. W., Radiant heating of dispersed particles, *Indust. Engng. Chem.* **48,** 10, 1819-1824, Oct. 1956.

After ascertaining themselves the reasonability of the assumption that, during the radiant heating of a particle, Nusselt number is constant (by demonstrating how small is the difference between the solution of energy balances, set up for two limiting cases: one of uniformly distributed heat sources inside the particle, presumably due to radiation; and the other, of an opaque particle surface) the authors solve, by means of Laplace transform, the lumped parameter, transient energy equation for nonvolatile particles exposed to thermal radiation. The algebraic inversion of the transformed solution is facilitated by noticing that one of the terms in the transform is negligibly small in comparison to others. In this way, two fundamental cases are analyzed: that of the initial behavior of a dispersion, when the effect of adjacent particles is negligible, and it is sufficient to consider only a single particle in an infinite medium; and that of densely dispersed particles. The effects of evaporation are then discussed.

On the basis of their analysis the authors describe the behavior of a cloud of dispersed particles, exposed to radiant heating, as follows: "The temperature of nonvolatile droplets rises swiftly to a pseudo-equilibrium value and finally rises more slowly as the finite amount of air associated with each particle is heated by conduction from the particle. Evaporation decreases the temperature of volatile droplets throughout the process and for sufficiently volatile materials the temperature may remain below the ambient temperature." A. K. Oppenheim, USA

895. Fryburg, G. C., Katz, N. H., and Simon, S. L., Effect of phosphate coatings on temperature of metal parts exposed to flame environments, *NACA TN* 3279, 20 pp., July 1956.

The effect of phosphate coatings on the temperature of metal specimens placed in a flame was investigated. Since flames contain large numbers of atoms and radicals that react on metal surfaces liberating heat, it was thought that a phosphate coating might decrease the temperature of the metal by poisoning the surface to these reactions.

Small cylindrical specimens of mild steel and S-816 alloy were placed in a natural-gas - air flame. For mild steel, uncoated specimens attained a temperature of 1900 F. This temperature remained constant, apparently because of lack of oxidation of the steel by the flame gases. Phosphated specimens attained a temperature nearly 200 F lower. For S-816 alloy, uncoated specimens reached a temperature of 1900 F, but the temperature fell to 1750 F, dropping rapidly at first and then gradually. This drop was apparently due to oxidation of the specimens. Phosphated specimens attained a temperature about 100 F lower, which was maintained even after 300 hrs in the flame.

A phosphate coating on S-816 alloy reduced the surface recombination of either hydrogen or oxygen atoms by a factor of 1/3. However, the oxide surface formed on S-816 alloy in the flame reduced these recombinations by a factor of 2/3. This result, along with evidence from emittance measurements, indicates that the temperature lowerings obtained in the flame by phosphating the surface arise primarily from the high emittance of the phosphate coating rather than from a poisoning action.

The phosphate coatings appear to have a high emittance, close to 1, and it is suggested that they might have an application on the outer surface of combustor cans.

From authors' summary

896. Cantle, G. S., and El Din Aref, M. N., The effect of end refractory surfaces upon the radiant heat absorption rate of banks of water-cooled tubes, *J. Inst. Fuel* **27,** 164, 438-445, Sept. 1954.

897. McGuire, J. H., Heat transfer by radiation, London, Dept. sci. indust. Res. and Fire Offices' Comm., Fire Res. spec. Rep. no. 2, v + 29 pp., 1953. 1s 6d.

898. Daskin, W., Evaporation from sprays, Proc. fourth Midwestern Conf. fluid Mech., Purdue Univ., Sept. 1955, 329-341.

Given the initial spray distribution and the evaporation law, one can compute the subsequent history of the spray. This paper gives a general treatment of the problem.

M. Tribus, USA

899. Ranz, W. E., and Marshall, W. R., Jr., Evaporation from drops, Part I, *Chem. Engng. Progress* **48,** 3, 141-146, Mar. 1952; **Part II, 48,** 4, 173-180, Apr. 1952.

Methods of predicting the evaporation rates of a single drop and the phenomena associated with the evaporation process are of importance in the analysis of chemical engineering operations involving dispersions in gases. Data on factors affecting the rate of heat and mass transfer for a spray droplet are important to the operations of spray drying, spray cooling, humidification, spray absorption, spray extraction, combustion, crystallization, dissolution, transfer in fluidized beds, and any other operation where transfer occurs between a continuous phase and a discontinuous phase which appears as spherical particles.

The present study of evaporation from drops is divided into the following parts: (1) Rate of heat transfer to the drop surface; (2) rate of evaporation and mass transfer from the drop surface; (3) temperature and concentration at the drop surface during evaporation; (4) effect on evaporation rate of original drop temperature, heats of solution and crystallization, and the way in which solid surfaces form. Range of Reynolds number of 0 to 200, usually encountered in spray-drying operations, was investigated. Correlations of heat- and mass-transfer rates were obtained from drop temperatures measured with 0.5 mil thermocouples. Drop diameters ranged from 0.06 to 0.11 cm, and air temperatures up to 220C.

Analogy between heat and mass transfer at low Reynolds numbers was confirmed, and the expression for the Nusselt number at zero Reynolds number was verified.

Studies of water drops containing dissolved and suspended solids furnished an insight into the mechanism of the formation of particles dried from drops. The results showed that when the solid (ammonium nitrate and sodium chloride) was in solution the drop evaporated initially as though it were saturated throughout, even though the average concentration was less than saturation. For drops containing insoluble materials, the initial evaporation rate corresponded to that of pure water.

Mathematical derivations are given and the experimental apparatus is described in detail. The critical evaluation of an extensive previous literature is noteworthy.

K. J. DeJuhasz, Germany

900. Chambre, P. L., On the dynamics of phase growth, *Quart. J. Mech. appl. Math.* **9,** part 2, 224–233, June 1956.

The growth of a solid, starting from negligible initial dimensions with either a plane, cylindrical, or spherical boundary, into a surrounding supercooled fluid is discussed and the differential equations are derived. The densities of the solid and fluid are assumed unequal. As a consequence, a convective motion occurs in the fluid having the characteristics of source or sink flow because of the fact that a unit mass of fluid occupies, on solidification, a volume differing from the volume originally occupied. Particular solutions are given for (a) densities assumed equal and (b) densities unequal. Prandtl number unity.

R. G. Nevins, USA

901. Dehn, R., A new method for the measurement of rapid fluctuations of temperature, *Brit. J. appl. Phys.* **7,** 4, 144–148, Apr. 1956.

The method described uses a photomultiplier in conjunction with an infrared image converter to measure changes in surface temperature of the cathode of an oscillating magnetron during microsecond pulses.

These instantaneous changes in temperature are displayed as pulses on the screen of a cathode-ray oscillograph. The procedure is given for calibrating the apparatus against an optical pyrometer. Changes as small as 2 C in 800–900 C have been detected (solid angle equals 2.5×10^{-3} steradians).

From author's summary

902. Rakov, K. A., Krol, L. B., Panasenko, M. D., and Bulgakova, N. V., Experimental boiler plant with once-through boiler for steam conditions up to 4266 psia, 1112 F, *Combustion* 28, 3, 42–47, Sept. 1956.

From 1946 to 1955 a great amount of work was done in the U.S.S.R. in the construction, operation, and investigation of an experimental steam-generating plant for 4266 psia, 1112 F. A 26,450-lb/h boiler went into operation in Nov. 1949. Up to September 1955 the boiler had been in operation for 17,500 hr; 11,250 hr with pulverized coal of low volatile content and 6250 hr with fuel oil. Only one rupture of a tube of 15 XM steel and several cracks in welded joints of EI-257 steel were observed during this period.

From authors' summary by W. Gumz, Germany

Combustion

(See also Revs. 746, 769, 847, 890, 896, 897, 902)

Book—903. Fifth symposium (international) on combustion. Combustion in engines and combustion kinetics, Univ. of Pittsburgh, Pittsburgh, Pa., Aug. 30–Sept. 3, 1954, New York, Reinhold Publishing Corp., 1955, xxvi + 802 pp. $15.

It has become a custom over the recent years to base the progress of certain fields of scientific endeavor, especially that of combustion, on comprehensive meetings with proceedings duly recorded in single volumes. As a result of this, the study of combustion grew up in importance to such an extent that today it embraces the whole field of the dynamics of reactive fluids (or, as preferred by von Kármán, the Aerothermodynamics). In addition, its subject matter became well consolidated, and the work of an historian, tracing its progress, vastly simplified.

Of all such meetings (of which today there is quite a number, e.g., Panel Meetings of the AGARD, Gasdynamic Symposium of the ARS), the pioneering are the Symposia (International) on Combustion, each of which marks a milestone in the progress of this branch of science. Consequently, the decision of the editors of *Applied Mechanics Reviews* to report on the Fifth Symposium by means of a single review written with a perspective, gained by approximately one year delay after the publication, seems well justified.

The events which lead to the Fifth Symposium were summarized as follows by Professor Hoyt C. Hottel in the introduction to the Symposium:

"The Third Symposium of this series—the first of the postwar series and the one which set the precedent of publications in a single volume—covered the whole field of combustion. The Fourth Symposium focused on the physics of combustion. The Fifth . . . attempted to compromise assignment of complementing the Fourth by concentration on the chemical kinetics of combustion reactions (half of the papers) while at the same time rounding out the program by the inclusion of 14 papers on engine combustion, 20 about equally spread among the burning of droplets, liquid propellants and solid, and 16 on diffusion flames, special techniques, spectra and disassociation energies."

The contents of the volume are grouped into ten sections.

The first section, entitled: "Review of problems on combustion in engines and kinetics of combustion processes," consists of 11 invited papers. Of these, six are devoted to unsolved problems in combustion concerned with specific applications, such as the internal combustion engine (by W. G. Lovell), the Diesel engine (by P. H. Schweitzer), the liquid-fuel rocket (by S. S. Penner and P. P. Datner), and solid propellant (by R. D. Geckler), the turbojet (by Peter Lloyd), and the ramjet (by J. P. Longwell); and five are on chemico-kinetic aspect of combustion. The latter group is made up of the comprehensive treatment "On the kinetics of elementary gas phase reactions at high temperatures" by Curt E. Shuler, the "Survey of collision processes in the combustion of hydrocarbons" by A. R. Ubbelohde, the concise report on recent developments in "Chemical kinetics of hydrocarbon combustion" by G. von Elbe, and the consideration of "Space heating rates and high-temperature kinetics" presented by W. H. Avery and including the description of the compact spherical reactor designed for the study of reaction kinetics, unhampered by flow-dynamic effects. The last invited paper, of J. Jennissen, describes a simple and promising theory of "Space requirements for combustion behind grids in a closed duct"—a case which lends itself to a unidimensional analysis.

The second section is devoted to "Combustion of fuel droplets" and consists of six papers. It includes the report of H. C. Hottel, G. C. Williams, and H. C. Simpson on an experimental study of "Combustion of droplets of heavy liquid fuels"; an empirical investigation of the effect of pulsating air flow on the combustion of fuel droplets by Seiichero Kumagai and Hiroshi Isoda; an

interesting study of H. Wise, J. Lorell, and B. J. Wood on "The effects of chemical and physical parameters on the burning rate of a liquid droplet," describing a careful experimental technique and a simple mathematical analysis of the results. This is followed by "An experimental study of the combustion of a fuel droplet" by Kiyosi Kobayasi, including a set of interesting photographs depicting the transient state from ignition to steady combustion of a benzene droplet; a closely related study of Niichi Nishiwaki concerned with the measurement of the evaporation and ignition lag of fuel droplets, made by the use of a movable combustion chamber and stationary silica filament from which droplets were suspended; and, finally, a concise summary of J. A. Browning and W. G. Krall's observations on the "Effect of fuel droplets on flame stability, flame velocity, and inflammability limits" investigated by means of kerosene-mist in air flames.

The third section on "Propellant burning" is made up of nine papers. It starts with a report on the "Preliminary measurements of the combustion time lag in a monopropellant rocket motor" by L. Crocco, J. Gray, and G. E. Matthews; continues with a "Study of the ignition lag of liquid propellants" by M. Barrére and A. Moutet; and includes papers on some particular aspects of combustion, of interest to rocket industry, such as the burning rates of hypergolic fluids, oscillation of the flame front between two droplets, fast reactions of anhydrous hydrazine with nitric acid, burning of nitrate esters, amonium nitrate, etc.

The fourth section is on "Combustion of solids" and consists of six papers mostly on experimental studies. They include observations on combustion of carbon particles in flames and fluidized beds, combustion mechanism of carbon, combustion of pulverized coal in a jet stream, absolute thermal decomposition rates of solids, some physical aspects of combustion of magnesium ribbons, and the ignition reactions of $Zn\text{-}C_6Cl_6\text{-}KClO_4$.

The fifth section has five papers in the field of "Diffusion flames and carbon formation" with an interesting study of carbon formation from C_2H_2 and CO in discharge tubes by A. G. Gaydon and A. R. Fairbairn.

The sixth section is on "Combustion in engines" and contains seven papers. Included there is the interesting investigation on "The effect of heat transfer on the maximum reaction rates of a homogenous reactor" by E. A. De Zubay and E. C. Woodward, who use a compact reactor with similar purpose but completely different geometry than that described by Avery (see first section); a theory of G. S. Bahn on a "Rational prediction of combustion efficiency for baffle-type combustors"; a report of E. H. W. Schmidt and F. Schoppe of experiments made in a cyclon combustor; a correlation of auto-ignition phenomena in IC engines, by J. C. Livengood and P. C. Woo; and four other papers devoted to some particular experimental aspects of the subject matter.

The seventh section is on "Special techniques." It contains five papers, including the description of the "Chemical shock tube" by H. S. Glick, W. Squire, and A. Hertzberg; the description of "Polarographic study of cool-flame oxidation products of hydrocarbons" by W. M. MacNevin et al. (working under the direction of C. E. Boord); the interesting application of the microwave technique, described by T. M. Sugden, to the study of the ionization in flames, or, more exactly, of alkali metals added to flame gases; the iodine absorption spectrum technique for temperature measurement, developed by N. J. Beck, K. Chan, O. A. Uyehara, J. G. Winans, and P. S. Myers; and the report on the "Studies of ionization in flames by means of Langmuir probes" (which were developed for the study of the properties of the electron plasma in electric discharges) by H. F. Calcote and J. R. King.

The largest is, of course, the section on the "Kinetics of combustion reactions" which consists of 45 papers. It starts, roughly in this order, with some 15 papers on the oxidation of hydrocarbons, and three on that of alcohols. There is one paper on free radicals in combustion processes and one on the effect of ionizing radiation of the nuclear beta-particles, obtained from the decay of tritium. Pre-flame reactions form the subject matter of three papers; two are specifically devoted to self-combustion of acetylene. Then there are four papers on explosion limits, two concerned with ethyl-nitrate vapors, one on the effect of methyl bromide on combustion kinetics, and one on the ethylene-oxide decomposition flame. Of particular interest is the paper of R. G. W. Norrish, G. Porter, and B. A. Thrush on the results obtained with the use of the, by now, well-known method of flash photolysis for kinetic studies of gaseous explosions. Also worth noting is the report of M. Steinberg and W. E. Kaskan on the ignition of combustible mixtures by shock waves—another method which has recently gained a good deal of popularity among the workers in reaction kinetics. Concerned also with wave effects is the comprehensive paper of S. Patterson on the structure of the reaction zone in a detonating explosive. D. G. H. Marsden and J. W. Linnett present an interesting report of their study on the "Recombination of oxygen atoms on surfaces." Then there is a paper on explosive decomposition and combustion of hydrazine, on sensitized ignitions in mixtures of hydrogen and chlorine, combustion studies of alkylsilanes, and of diborane-oxygen mixtures. Noteworthy is the publication of H. G. Wolfhard and W. G. Parker on the "Spectra and combustion mechanism of flame supported by the oxides of nitrogen"; and A. L. Berlad and A. E. Potter's theory from which the quenching effects of various surface geometries can be predicted. The study of C. Foure of stationary flames in cylindrical flow of homogenous air-hydrogen mixtures, and that of A. T. Touma and F. H. Verhoek on the kinetics of oxygen uptake by cyclohexene in the liquid phase, conclude the array of papers in the section on kinetics.

The last section is concerned with "Flame spectra and dissociation energies." It consists of the report of K. Wohl and F. Welty on the spectrophotometric traverses through flame fronts; R. E. Ferguson and H. P. Broida's experiments on atomic flames; the observations of W. G. Agnew, J. T. Agnew, and K. Wark on infrared emission from stabilized cool flames; G. J. Minkoff, A. J. Everett, and H. P. Broida's report on ultraviolet spectrophotometry of low pressure explosions; Shoen's report of the experimental study of the photodecomposition of formaldehyde; and G. A. Hornbeck's "Spectroscopic determination of the dissociation energy of the OH radical."

The volume concludes with two reports of panel discussions: one on heterogeneous burning with H. C. Hottel presiding and D. Altman, G. C. Williams, and S. Ergun as discussion leaders; and the other, concerned with the appraisal of the status of the theory of the kinetics of combustion reactions, with A. R. Ubbelohde as chairman, and G. Porter, J. M. Richardson, K. E. Shuler as panel members.

To sum up, the distinguishing mark of the Fifth (International) Symposium on Combustion is, in the opinion of this reviewer, the wealth of experimental data, and information on experimental techniques especially suitable for the study of kinetics of fast reactions, such as the homogeneous reactor, the flash photolysis, and the shock tube.

A. K. Oppenheim, USA

904. Albright, L. F., and Alexander, L. G., Stable cyclonic flames of natural gas and air, *Jet Propulsion* **26,** 10 (part 1), 867–873, Oct. 1956.

Investigation was conducted to determine quantitatively the characteristics of flames stabilized by cyclonic motion in mixtures of air and natural gas. Air and gas under pressure were metered by sharp-edged orifices. Combustion experiments were conducted with cyclonic combustion nozzle and also with straight and curved ducts. Temperature and gas analysis traverses were made across flames.

Gases flowing cyclonically from a nozzle burned stably at superficial velocities up to 100 fps. Temperature of flames was sometimes higher than 2400 F. Extremely stable flames were

tained when mixtures of air and natural gas flowed cyclonically 0.5-in. ducts of various lengths. Flames stabilized at super-cial velocities up to 700 fps. Flame stabilization results from verse flow toward nozzle along its axis.

Reviewer believes investigation contributes valuable informa-ion concerning cyclonic flames. M. Popovich, USA

905. Kumagai, S., Combustion of fuel droplets in a falling hamber with special reference to the effect of a natural con-ection, *Jet Propulsion* **26,** 9, p. 786 (Technical Notes), Sept. 956.

Photographic and graphic results are presented for burning heptane and ethyl alcohol fuel droplets under constant accelera-ion fall. The results include experimental data on the effect of cceleration during the fall of a droplet on the evaporation onstant. Acceleration rates from 0 to 1g are studied experi-entally. The detailed discussion is to be presented by the uthor at the 6th International Symposium on Combustion to be eld at Yale University. Y. S. Touloukian, USA

906. Green, L., Jr., Observations on the irregular reaction of olid propellant charges, *Jet Propulsion* **26,** 8, 655–659, Aug. 956.

Author emphasizes the need for a clear terminology concerning "unstable burning." The rocket engineer is interested in a mooth pressure-time curve of the rocket motor, without erratic "secondary peaks." Typical firing curves with such unwanted ressure peaks are shown for various solid propellant charges. On the other hand, the combustion scientist discussing in-tability is concerned with high-frequency pressure oscillations ot recorded by low-frequency instrumentation in rocket tests. A hypothetical coupling mechanism of high-frequency instability nd gross pressure peaks is discussed.

H. Behrens, Germany

Acoustics

907. Peschka, W., Speed of sound in dissociated gases (in erman), *Öst. Ing.-Arch.* **10,** 2/3, 244–247, 1956.

Author considers a gas at so high a temperature that dissocia-ion takes place. Assuming that each constituent follows the deal gas law, he derives an expression for the square of the peed of sound v which does not contain the (variable) ratio c_p/c_v. He shows how the expression for v^2 can be evaluated with he aid of an enthalpy-entropy diagram. The theory is applied to ydrogen gas in the range from 2000 to 10,000K. Curves are lotted giving v^2 as a function of temperature for pure H_2, for pure H, and for the mixture of H_2 and H at 1, 10, and 100 atmospheres.

R. Heller, USA

908. van Itterbeek, A., and de Rop, W., Measurements on the elocity of sound in air under pressures up to 20 atm combined ith thermal diffusion, *Appl. sci. Res.* **(A) 6,** 1, 21–28, 1956.

An acoustical interferometer has been constructed to measure elocity of sound in gases under high pressures and low tempera-ures. Velocity measurements have been carried out down to the oiling point of liquid propane. During the measurements the nfluence of thermal diffusion could be observed. A few measure-ents are done by measuring the change of the velocity as a unction of time. From authors' summary

909. Ying, C. F., and Truell, R., Scattering of a plane longi-udinal wave by a spherical obstacle in an isotropically elastic olid, *J. appl. Phys.* **27,** 9, 1086–1097, Sept. 1956.

Calculations have been made for longitudinal waves of the cattering cross sections of elastic spheres, fluid spheres, spherical cavities, and rigid spheres embedded in isotropic solid materials. The scattering cross sections have been compared with the Rayleigh scattering cross sections of a fluid sphere in a fluid. In the Rayleigh region, i.e., when the acoustic wave length is large compared to the size of the scatterer, elastic spheres, fluid spheres, and spherical cavities all follow an equation of the form $\gamma = (4\pi/9)\, g k_1^4 a^6$ where γ is the scattering cross section, $k_1 = \omega/v$ = ratio of angular frequency to velocity, and a is the radius of the scatterer. The values of g depend on the elastic constants of the material and, in general, are larger than those calculated for fluid spheres. In the case of a rigid sphere, the scattering formula shows less dependence on the frequency and radius. Numerical values are given for several materials.

W. P. Mason, USA

910. Keller, J. B., Reflection and transmission of sound by a moving medium, *J. acoust. Soc. Amer.* **27,** 6, 1044–1047, Nov. 1955.

The reflection and transmission of sound by a moving medium are investigated theoretically and the reflection and transmission coefficients are determined. These coefficients are found to depend only upon that component of the velocity of the medium which lies in the plane of incidence. The reflection coefficient increases with the velocity of the moving medium until a velocity is reached at which total reflection occurs. Total reflection persists until a still higher velocity is reached above which the reflection coefficient decreases as the velocity increases.

From author's summary

911. Rao, B. R., and Rao, P. V., Determination of shear wave velocities in isotropic solids by a modified wedge method, *Acustica* **5,** 4, 217–218, 1955.

The principle and experimental details of a new method of determining the shear wave velocities in isotropic media are described. Shear wave velocities are determined in some metals and some Indian rock specimens and are compared with those obtained by other methods. The advantages of this method are discussed briefly. From authors' summary

912. Franken, P. A., A theoretical analysis of the field of a random noise source above an infinite plane, *NACA TN* 3557, 20 pp., Nov. 1955.

This paper is a theoretical study of the sound field from a random noise source above ground as measured by a receiver with finite band width. Sound field has been smoothed by the use of a random noise source rather than a pure tone as used by other investigators. Stress has been laid on the fluctuations in space due to interference.

Level fluctuations as a function of receiver band width for the case of a random noise source with a constant power spectrum have been studied. Sound field is divided into two regions. In the first, sound pressure level fluctuates at the rate of about 6 decibels per doubling of distance, and in the second at the rate of 12 decibels monotonically per doubling of distance.

G. S. Verma, India

913. Mason, W. P., and Bommel, H. E., Ultrasonic attenuation at low temperatures for metals in the normal and superconducting states, *J. acoust. Soc. Amer.* **28,** 5, 930–943, Sept. 1956.

At temperatures below 10K and frequencies above 10 Mc/s, the attenuation of vibrations in a metal is caused mainly by relaxation of conduction electrons. Damping drops rapidly but continuously when metal becomes superconducting. Existing observations, and theories due to Mason, Morse, Kittel and Pippard are surveyed. New observations are reported on single crystals of spectroscopically pure tin, where long electron-free path leads to large damping. All components of the elastic and relaxation tensors are determined for this crystal, and the frequency dependence is in general agreement with Pippard's theory for both large and small

ratios of acoustical wave length to electron mean free path. Sound velocities were determined with a newly designed circuit, and a drop of 4.5 parts in 10^7 was found at the transition temperature, in agreement with Olsen's measurement of the change of critical magnetic field with temperature.

F. R. N. Nabarro, So. Africa

914. Wada, Y., and Yamamoto, K., Temperature dependence of velocity and attenuation of ultrasonic waves in high polymers, *J. phys. Soc. Japan* **11,** 8, 887–892, Aug. 1956.

The temperature dependence of ultrasonic velocity and absorption is studied over a temperature range of −60C to +90C for frequencies ranging from 120 Kc to 7.3 Mc. Standard methods are used; the measurement of the critical reflection angle (from transmission phenomena) and transmission loss in the megacycle range and the composite bar resonance method at 100 Kc. It is found that the ultrasonic velocity, in the first approximation, is determined by the intermolecular free volume, and that the temperature coefficient of velocity exhibits an abrupt change in the glass transition region similar to the thermal expansion coefficient.

Reviewer believes that the data presented is accurate and useful to the ultrasonic engineer who uses plastic.

M. S. Weinstein, USA

915. Tarnoczy, T., Explanation of the diffusion increasing effect of ultrasound (in Hungarian), *Magyar fiz. Fóly.* (3) **4,** 1, 67–74, 1956.

The effect of increasing diffusion by ultrasound results from the combined effects of several physical factors. Author experimentally selects the effect of these different factors, and proves the proportion of each in one certain laboratory experiment.

S. Apati, Hungary

916. Watkins, C. E., and Durling, Barbara J., A method for calculation of free-space sound pressures near a propeller in flight, including considerations of the chordwise blade loading, *NACA TN* 3809, 68 pp., Nov. 1956.

Rotating pressure pattern of propeller can, at any point of disk, be resolved into Fourier series in time. Each harmonic represents an oscillating pressure jump, radiating sound. Gutin [*NACA TM* 1195], Hubbard and Regier [AMR **4,** Rev. 3354], and Garrick and Watkins [AMR **7,** Rev. 1992] have derived the radiation with respectively increasing generality, e.g., from test-stand to flight conditions. Last-named ultimately idealize blades as infinitely narrow, hence err in harmonic distribution. Present paper develops their general results for finite-width blades, uniform chord loading. Basic integrals (applicable also for nonuniform loading) for a number of harmonics in radiated sound are evaluated and tabulated for near field. Means for Fourier development of broken-line load-curve approximations are indicated. Radial distributions of force are considered as well as concept of an effective radius. Evaluation of near-field sound for some specific 16-ft propellers is made, comparing both approaches. Effects of chord loading on harmonic distribution are also exhibited. H. S. Ribner, Canada

917. Gerrard, J. H., An investigation of the noise produced by a subsonic air jet, *J. aero. Sci.* **23,** 9, 855–866, 873, Sept. 1956.

To investigate theoretical prediction of Lighthill, measurements have been made of the sound field of a 1-in. air jet. Mach number was varied from 0.3 to 1.0 at frequencies from 30 to 10,000 cps. Results indicate that the observed noise field is well represented, qualitatively, by the theory. A quantitative verification requires measurements of the turbulent structure of the jet.

From author's summary by A. Petroff, USA

918. Anderson, A. B. C., Vortex-ring structure-transition in a jet emitting discrete acoustic frequencies, *J. acoust. Soc. Amer.* **28,** 5, 914–921, Sept. 1956.

The shedding of vortexes from the boundary of a jet is more or less periodic. Periodic jet tones begin to be audible above the background noise at a Reynolds number of about 2000 for the jet from a thin orifice, diameter ¼ inch, where the orifice plate thickness is the significant dimension. Subharmonic tones are generated by the periodic downstream coalescence of vortexes. When the vortex shedding frequency (determined from a set of shadowgraphs) is plotted against *Re*, the curves are straight lines for each frequency, and intersect at the origin for low *Re*. At high *Re*, the lines break slope, and the intersection occurs at about *Re* 1150. Higher frequencies are radiated from upstream points. Finally, even though vortexes coalesce, their translational velocity remains substantially constant. The paper is illustrated by a beautiful set of shadowgraphs. V. Salmon, USA

919. Callaghan, E. E., Howes, W. L., and Coles, W. D., Near noise field of a jet-engine exhaust. II—Cross correlation of sound pressures, *NACA TN* 3764, 53 pp., Sept. 1956.

Paper presents results of correlation measurements of the pressures measured by two microphones having a variable spacing. The correlation measured is defined as $R = \overline{p_1 p_2}/(\overline{p_1^2})^{1/2}(\overline{p_2^2})^{1/2}$ where p_1 and p_2 are the instantaneous fluctuating pressures at two points. Data are presented for the correlation of the over-all pressures as well as correlation with the signals filtered with various filters having a frequency range from 100 to 1000 cps. Measurements are made just outside of the jet flow region of a current 10,000 thrust engine, in the region where structural damage to aircraft components is common.

The information is of interest with regard to calculations of response of structures to jet noise and also with regard to shedding further light on the sources of jet noise. In general, the correlation distances for a given frequency band very near the nozzle are shorter than at some distance from the nozzle.

A. A. Regier, USA

920. Lippert, W. K. R., An extended method of measuring symmetrical filters, *Acustica* **5,** 5, 269–273, 1955.

Paper presents the theory and experimental procedure for determining the characteristic reflection and transmission factors of symmetrical filters and discontinuities with a reflecting output duct. From author's summary

Ballistics, Detonics (Explosions)

(See Rev. 906)

Soil Mechanics, Seepage

(See also Revs. 649, 667, 672, 675, 676, 878, 879, 928, 930, 931, 933)

Book—921. Streck, O., Soil and hydraulic engineering in practical applications [Grund- und Wasserbau in praktischen Beispielen. Bd. I. Grundbau/Hydrostatik/Grundwasserbewegung], 2nd ed., Berlin, Springer-Verlag, 1956, viii + 416 pp. DM 31.50.

Writer deals with problems of soil and hydraulic engineering by means of practical cases, in each of which a particular construction is planned and its dimensions calculated, according to the water, soil, and wave pressure acting on it. Different soil- and water-retaining constructions are thus treated, as well as some cases of seepage, drainage, and ground-water lowering by well-point system.

In this second edition, the writer has added some chapters on geology and soil mechanics.

Although the book has little research value, it will be useful to students and engineers in practice.

F. C. de Nie, Holland

922. **Schneebeli, G., A mechanical analogy for soils without cohesion** (in French), *C. R. Acad. Sci. Paris* **242**, 2, 125–126, July 1956.

923. **Leonards, G. A., Strength characteristics of compacted clays,** *Trans. Amer. Soc. civ. Engrs.* **120**, 1420–1479, 1955.

924. **Schmertmann, J. H., The undisturbed consolidation behavior of clay,** *Trans. Amer. Soc. civ. Engrs.* **120**, 1201–1233, 1955.

925. **Foster, C. R., Reduction in soil strength with increase in density,** *Trans. Amer. Soc. civ. Engrs.* **120**, 803–822, 1955.

Laboratory and field data are presented which show that, for certain given moisture contents, increases in density result in increases in strength as measured by the California Bearing Ratio (CBR) up to a certain density, after which increases in density result in a decrease in CBR. Confirmation of the decrease in strength is presented as field observations of the behavior of a silty clay soil in accelerated traffic tests. The decrease in strength is believed to be the result of the development of pressure in the void phase of the soil structure. As long as the combination of moisture and density is such that no pore pressures develop, increases in strength occur with increase in density. When pore pressures develop, further increases in density produce decreases in strength. From author's summary

926. **Lamb, T. W., The storage of oil in an earth reservoir,** *J. Boston Soc. civ. Engrs.* **43**, 3, 179–241, July 1956.

927. **Fischer, K., Calculation of settling of circular foundations** (in German), *Bauingenieur* **31**, 7, 257–259, July 1956.

Surface settlement of a semi-infinite elastic solid under a uniform load in a ring-shaped area is obtained by superposition of two solutions for a uniform load in a circular area. Tables convenient for numerical computations are added.

T. Mogami, Japan

Micromeritics

(See also Revs. 649, 755, 926, 933)

928. **Stutzman, L. F., and Thodos, G., Adaptation of friction factors to the flow of fluids through consolidated formations,** *J. Petr. Technol.* **8**, 11, 59–62, Nov. 1956.

The conventional equations for linear flow of fluids through porous media are specific to laminar or turbulent flow. Authors present a method for the solution of problems when the flow is in the transition region or when it is radial, as into a well. For linear flow, the method follows the conventional method for pipes, using a plot based on empirical data with the friction factor a function of a modified Reynolds number. For radial flow in which the velocities are constantly changing, the expression for pressure drop is expressed in differential form and integrated graphically, neglecting changes in density and viscosity.

W. DeLapp, USA

929. **Schwarz, N., Two-phase flow through porous media** (in Dutch), *Ingenieur* **68**, 18, M.1–M.7, May 1956.

The flow of one phase through a porous medium could be mathematically formulated a hundred years ago, but for two phases (e.g., oil and water) this is, in a strict sense, not yet possible even today. The simplifications that have been introduced in the various attempts to arrive at a mathematical description, and the results so obtained, are discussed.

Another approach to the problem is by means of model studies. By dimensional or inspectional analysis the variables that govern two-phase flow can be combined to dimensionless groups, with the aid of which the process can be defined. Laboratory tests can then be designed with the purpose of determining the functional relationship between the groups. In principle the results are generally applicable also to many natural oil-bearing rocks, the dimensions of which are some orders of magnitude larger than the laboratory models.

The results of such model studies are of great importance to the technique of recovering petroleum, since crude oil occurs in underground porous formations from which it is displaced by water and/or gas. From author's summary

930. **Iffly, R., Study of flow of gas in porous media. Application for the determination of morphology of rocks** (in French), *Rev. Inst. fr. Petrole et Ann. Comb. liq.* **11**, 6, 757–796, 1956.

In this essentially experimental study, author endeavours above all to determine the law governing the flow of gas through porous media. The study of the flow of liquids in these media does not present any special difficulty; the loss of head and the rate of flow are two quantities which usually are proportional to each other. On the contrary, in the case of gases, the loss of head increases much more rapidly than the rate, all other things being equal. It is pointed out that this anomaly should be imputed to the existence of additional power loss by kinetic irreversibilities and, therefore, the too often admitted theories of turbulent flow and polytropic flow could not be retained. Actually, this law has a very simple form, including both linear and square terms with two coefficients related to the characteristics of the porous medium.

Assuming a statistical definite shape for the porous channels, the coefficients can be interpreted, thus giving numerical information as to the size of these channels. The good agreement between the flow experiments and the capillary studies for many porous media shows that the initial assumptions are close to reality.

Conversely, knowledge of the morphology of a homogeneous rock permits calculation of the gas-flow law in this rock. For any such gas-bearing, standard back pressure tests could be eliminated, which is of obvious interest. From author's summary

931. **Milojevic, M., Determination of the maximum discharge of vertical wells and underground water pressure,** *Naše Gradevinarstvo* **10**, 1, 34–37, 7 diagrams, Jan. 1956.

Charles Jaeger's theory is thoroughly discussed and diagrams simplify the determination of maximum discharge and critical depth. Author uses the Reynolds number for the circumference of the well as the criterion to prove the validity of Darcy's law in the vicinity of the well and accuracy of solutions, and describes an improved method for determination of values K and R of Jaeger's theory. Further reference is made to Babbitt, Doland, and Czertousov. J. J. Polivka, USA

Geophysics, Meteorology, Oceanography

(See also Revs. 649, 780, 817, 818, 825)

932. **Homma, S., Rayleigh waves in a medium with superficial double layers,** *Geophys. Mag., Tokyo* **27**, 1, 17–34, Jan. 1956.

Author investigates case of plane, surface waves in semi-infinite medium having two surface layers with different properties. For very long wave lengths, equations reduce to those of Rayleigh waves; and for very short wave lengths, reduce to those of Rayleigh waves in surface medium and Stoneley waves along the two interfaces. Analysis involves extremely lengthy equations and a particular numerical solution is given for variation of phase velocity with wave length. G. W. Housner, USA

933. Van Nostrand, R., Continuous velocity logging (in French), *Rev. Inst. fr. Petrole et Ann. Comb. liq.* **11,** 6, 743–756, 1956.

Continuous velocity logging is one of a variety of methods designed to obtain information in a bore-hole by physical measurements. Velocity logs were originally devised to get seismic velocity information more conveniently and more economically than can be done by conventional well geophone surveys. However, continued experience with velocity logs has shown that they have many other uses, some of which appear to be of even greater importance than that for which the tool was originally designed. For example, stratigraphic correlation over a line fifty kilometers long, by means of velocity logs, is very well illustrated by an example near Midland, Texas. Many times, the determination of formation boundaries is possible on velocity logs when not on other types of logs; examples are shown from Gonzales County, Texas, and from the Paris Basin, France.

A second purpose of velocity logs is to help understand the origin of signals on reflection seismograms. This understanding is best accomplished through the preparation of synthetic seismograms. A comparison of synthetic seismograms with real seismograms illustrates the principles involved and shows that the idea of a synthetic seismogram is valid. A further use of velocity logs lies in the direct detection of gas and oil in bore-holes. It has been found that in hydrocarbon-saturated sands the seismic velocity decreases whereas the resistivity increases. On the contrary, when the sands are of low porosity or are water-saturated, the velocity increases. Several examples of off-shore wells in Louisiana illustrate this principle, and the presence of oil and gas was correctly predicted on the basis of this principle.

From author's summary

934. Takahashi, T., Analysis of the dispersion curves of Love-waves, *Bull. Earthq. Res. Inst., Tokyo Univ.* **33,** part 3, 287–296, Sept. 1955.

Analysis was made on propagation of Love-waves over surface of two-dimensional heterogeneous medium to extend theory on stratified system to more general case. Problem was solved approximately by so-called W.K.B. method and formula of wave dispersion was presented. In course of study author made some assumptions which could be considered reasonable from geophysical viewpoint. Numerical calculation made on simple system, in which rigidity increases linearly with depth whereas density is constant, agrees fairly well with result of Y. Satô, who studied the same case more accurately [title source **30,** 1, 1–12, Mar. 1952].

Author also presents method to determine crustal structure with dispersion curve of Love-waves calculated from seismograms.

K. Kasahara, Japan

935. Goodman, L. E., Rosenbluth, E., and Newmark, N. M., A seismic design of firmly founded elastic structures, *Trans. Amer. Soc. civ. Engrs.* **120,** 782–802, 1955.

Authors outline basis for design of elastic structures such that all parts will have equal probability of withstanding ground motion. Earthquakes are represented as a succession of random motions. Response of structure in each of its natural modes is treated through use of influence functions. Using probability theory, formulae are derived for expected response as a function of time. Subject to certain restrictions, the maximum response is also derived.

J. H. Huth, USA

936. Hishida, K., On the coastal water and its relation to the oceanic water; statistical study on the specific gravity of sea waters in the monthly interval, *Oceanogr. Mag.* **7,** 1, 1–4, June 1955.

937. Hishida, K., On the coastal water and its relation to the oceanic water; analytical study on the annual variation of coastal surface water temperature, *Oceanogr. Mag.* **7,** 1, 5–10, June 1955.

938. Gambo, K., The topological effect upon the jet stream in the westerlies, *J. meteor. Soc. Japan* **34,** 1, 24–28, Mar. 1956.

The titled subject is discussed in the stationary case, using the equivalent barotropic model of the atmosphere and the geostrophic assumption for the wind speed which are conventionally used in the field of numerical weather prediction.

The salient feature of author's treatment is that the wave pattern of finite amplitude is obtained by solving the nonlinear equation. Further, he computed numerically the stream pattern produced by the Himalayas and compared the calculated with the observed mean wind speed for the winter season obtained by Yeh and Mohri.

K. Miyakoda, Japan

939. Kusano, K., Sumino, M., and Kikuchi, T., Forecast of rainfall distribution in small scale (in Japanese), *Tenki* **3,** 2, 52–57, Feb. 1956.

A simple method of predicting rainfall is presented. The forecasting scheme is based on the continuity relation for water vapor, where the term of time derivative of mixing ratio is neglected. Authors further attack the problem of predicting precipitation amounts in small scale which are superposed on the large scale one, considering the effect of forced upward motion of moist air along the mountain surface. Results of practical forecasts seem very promising, though the treatment of water vapor is incomplete.

K. Miyakoda, Japan

940. Anonymous, Standard atmosphere—tables and data for altitudes to 65,800 feet, *NACA Rep.* 1235, 114 pp., 1955.

941. Gentry, R. C., Wind velocities during hurricanes, *Trans. Amer. Soc. civ. Engrs.* **120,** 169–179, 1955.

The structure of hurricanes, the duration of hurricane-force winds, and the distribution of wind velocity in hurricanes are investigated in the paper. The variation of wind velocity with height and the probability of hurricane occurrence are also examined. Author presents examples of the highest measured velocities and estimates of the highest velocity winds ever observed in the United States.

From author's summary

942. Radojkovic, M., What wind intensity should be considered for design of structures? *Naše Gradevinarstvo* **10,** 1, p. 33, Jan.

Par. 23221 of the Yugoslav building code PTP 2 is criticized. This paragraph under certain circumstances would reduce the wind load 17.5 lb/sq ft (90 kg/m²) for buildings from 33 to 99 ft (10 to 30 m) high to a very small intensity of 5 lb/sq ft (25 kg/m²). Reference is made to German standard regulations DIN 1055 specifying wind load 16.5 lb/sq ft (80 kg/m²) for buildings up to 63 ft. high and 22.5 lb/sq ft for buildings up to 328 ft (100 m) high, and to American AISC specifications of approximately same intensity.

J. J. Polivka, USA

Marine Engineering Problems

(See also Revs. 864, 868)

943. Ferguson, J. M., and Parker, M. N., Model resistance tests on a methodical series of forms. The effect of changes in block coefficient in the range 0.65–0.75 and the resistance of 0.675 block coefficient forms with bulbous bows, *Trans. Instn. nav. Arch. Lond.* **98,** 1, 1–30, Jan. 1956.

944. Strandhagen, A. G., and Kobayashi, F. M., Wave resistance on trailing ships, Proc. fourth Midwestern Conf. fluid mech., Purdue Univ., Sept. 1955, 211–222.

Authors calculate the wave resistance of a ship moving in the wake of a similar ship by the method of sources and sinks. The two ships move with the same uniform velocity, one behind the other. They find that large reductions in wave resistance of the trailing ship are obtained by properly adjusting the distance between the ships.

Reviewer notes that the velocity potential for the motion of the two ships has been obtained by adding the velocity potentials due to the motion of each in the absence of the other. Such a procedure essentially neglects the interaction between the two ships. However, it may be considered as a first approximation.

S. D. Nigam, India

945. Falkemo, C., On the possibilities of estimating the towing resistance of ships by tests with small models, Part II, *Trans. Roy. Inst. Technol. Stockholm* no. 103, 15 pp. + 6 plates, 1955.

Investigations at the Ship Testing Laboratory of the Royal Institute are continued. In the previously reported part I [AMR **7,** Rev. 1256] of this same investigation, 2-m models appeared unsatisfactory, as compared with 1- and 6-m, for towing resistance. Corrections are required for wetted surface of model laminar flow, as compared with the general turbulent area. The laminar region is determined by a soluble-film technique. This part II continues 1-, 2-, and 6-m tests, and makes available many clear, photographic reproductions. Questions of model size, Reynolds number, laminar regions, flat plate friction, form, and calculation of coefficient residual resistance are examined.

Tests on 9 models, size scales from 1:12, 5 to 1:160, were added to those in part I. Stimulated turbulence was omitted, and the 6-m models were no longer available at time of soluble-film tests. Total resistance can be equated to product of dynamic pressure, area, coefficient of total resistance. Dimensionless plots of coefficient show smooth increase with *Re*. A calculated friction coefficient plot for plane surface is given, decreasing with increasing *Re*, assuming Schoenherr's line. Froude number lines are superimposed. Laminar regions were traced on transparent paper, on model, showing wave contour and transitions, and vortex paths. Areas of laminar regions were plotted against speed.

Soluble films give a good idea of extent and shape of laminar regions, for 2-m models at *Re* greater than 10 million, but not for 1-m models. Results for turbulent flat plate friction depend on Schoenherr's line and assumption for friction coefficient depending on form. Plots show agreement, and amounts of variation, of coefficient of friction resistance for 2-m compared with 6-m models.

E. Smith, USA

946. Sizov, V. G., Parametric resonance phenomenc in rolling of ships (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* no. 20, 21-24, 1954.

947. Munro-Smith, R., The weight equation in ship design, *Shipbuilder* **63,** 575, 184–185, Apr. 1956.

948. Vasarhelyi, D. D., and Hechtman, R. A., Welded reinforcement of openings in structural-steel tension members, *Welding J.* **35,** 9, 421s–430s, Sept. 1956.

Results are reported on tests of over 40 specimens of plain-carbon semikilled steel plates having holes with various types of reenforcement. Specimen sizes are 36 × 1/4 in., 36 × 1/2 in., and 48 × 1/2 in. The holes in the specimens were both circular and rectangular with rounded fillets. The specimens were loaded in tension in a 2,400,000-pound testing machine. Strain gages were used on all specimens. The tests included both room temperature and low temperatures down to −46 F.

Failure of the specimens occurred both by shear and by cleavage. Cleavage fracture was accompanied by a less efficient stress and energy distribution than shear fracture. The results suggested that the low-energy cleavage fracture of some welded members may be caused by the lack of sufficient plastic flow preceding fracture, with the corresponding reduction in the plastic stress concentration factor. The load-carrying capacity of the plates was increased by adding reenforcement. No significant change in the energy-absorbing capacity of the plates was brought about by increasing the percentage of reenforcement.

The tests showed an inherent low capacity of a member containing an opening to absorb energy. The efficiency, with respect to energy absorption to ultimate load, ranged from 6 to 36%, with only 8 specimens having values in excess of 25%. Strengthwise it was found that reenforcement could raise the strength of the plate beyond that for a solid plate. In some instances, increasing the amount of reenforcement moved the point of failure from a section including the opening to a section just outside the reenforcement.

The results of this comprehensive investigation should furnish information of high value to those concerned with the design of steel plate members having large openings.

S. Levy, USA

949. McGoldrick, R. T., A theorem on bending stresses in rotating shafts, *David W. Taylor Mod. Basin Rep.* 947, 9 pp., June 1955.

When a strain gage is mounted on the circumference of a ship's propeller shaft, the question arises as to the proper location, for measuring bending stresses.

For a two-bladed propeller, the blade-frequency vibration will set up first-order and third-order stress components. These, combined with effects of thrust eccentricity and gravity, produce a bending stress whose resultant does depend on the gage location.

However, for a three-, or more, bladed propeller, the normal bending stress can be represented in an equation showing the product of Young's modulus, shaft radius, and of a sum of terms containing a sine, a cosine, and two Fourier series. The orders of excitation are usually: the zero order due to gravity or eccentricity, the first order due to unbalance in propeller or shaft or propeller-blade pitch unbalance, and then the blade frequency order or integer multiple thereof. The amplitudes of the stress components are found by harmonic analysis of the oscillograms for strain.

Now, shifting the gage location changes the sine and cosine components by the same phase angle so that the resultant is always the square root of the sum of the squares of the two terms. Thus, as long as identical orders of stress are not set up by different orders of vibration, the amplitudes of the stress components will be the same regardless of the position of the strain gage on the propeller shaft.

E. Smith, USA

950. Brehme, H., The propeller slip diagram, *European Shipbldg.* **5,** 6, 137–145, 1955.

Letter to the Editor

951. Concerning AMR 9, Rev. 4061 (December 1956): Anonymous, Thermal problems of atomic power stations.

The authors of the above paper are C. E. Lundgren and C. Seippel.

The editors regret this error.

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FRIEDMAN, B., Principles and techniques of applied mathematics (Applied Mathematics Series), New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1956, ix + 315 pp. $8.

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KEUNE, F., Der gewölbte und verwundene Tragflügel ohne Dicke in Schallnähe, Forschungsberichte des Wirtschafts-und Verkehrsministeriums Nordrhein-Westfalen, no. 279, Köln, Germany, Westdeutscher Verlag, 1956, 30 pp.

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